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ITS ORGANIZATION AND MANAGEMENT

C. C. FURNAS
Director, Cornell Aeronautical Laboratory
EDITOR

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Preface

This volume was written by representatives of various member companies of Industrial Research Institute, Inc., which has as its objectives:

1. To promote, through the co-operative efforts of its members, improved, more economical and more effective techniques of organization, administration, and operation of industrial research.
2. To develop and disseminate information as to the organization, administration, and operation of industrial and social activity of the nation.
3. To stimulate and develop an understanding of research as a force in the economic, industrial and social activity of the nation.
4. To promote high standards in the field of industrial research.

This group of writings is a step toward the fulfillment of those objectives.

Through publication, the thoughts and experiences of a number of successful executives with long-standing research experience, representing a good cross-section of American industry, are made available to those who may have an interest in the organization and management of industrial research activities. The breadth of this audience is an indeterminate quantity, but certainly all those having any connections with industrial research laboratories, from laboratory assistant to corporation president, have a potential interest in organization and management of this activity which is becoming a dominant part of the American scene.

In the preparation of this monograph no attempt was made to place the authors in an editorial strait-jacket. Though each chapter was written in general conformance to a predetermined outline, each remains an individual contribution. Naturally, then, there are wide variations in style of presentation. Readers will also be able to detect something less than 100 per cent agreement among the authors on some items that are matters of opinion. Though every effort has been made to eliminate unnecessary duplication, there are a few instances of overlapping of subject matter, where a correlation of topics is required. Only in this way can the reader have the benefit of the individual views and knowledge of the experienced men who make up the list of authors.

This is not a management recipe book, nor a collection of *do*'s and *don't*'s. The organization and management of industrial research constitute an art that can never be encompassed by a book of rules. But there are certain principles and experiences which have repeatedly proved to be applicable and valuable. A number of them are presented in this volume. They should be useful as a guide to those who are, or expect to be, active in the planning of industrial research organizations and programs.

C. C. FURNAS, *Editor*

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C. C. Furnas, *Editor*

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CHAPTER I

The Philosophy and Objectives of Research in Industry

From his very beginning, man has been a researching animal. The utilization of fire, the invention of the wheel, of weaving, of the planting and harvesting of crops, represent his earliest successful attempts to better nature. There was no fixed philosophy back of these early gropings, no organized thinking, no planning—only an innate curiosity, a willingness to "try and see," perhaps a vague understanding of a relation between cause and effect, spiced with rudimentary ambition.

This early inventiveness was by no means scientific. Not until men had collected a great deal of information about the natural world, had perfected their processes of pure reasoning, and had developed a true thirst for knowledge did they become "scientific."

For many generations science and invention evolved along parallel paths, with few cross-overs. When the paths finally merged to an effective degree the inevitable result was an industrial revolution which is probably, even now, only well started. Inevitable, too, as industry became larger and its technology more complex, was the organization of groups assigned the task of applying their full efforts toward welding scientific knowledge and inventiveness into new and better products and processes. Thus arose modern industrial research.

It would be erroneous to imply that no advances can be made in industry without a formal research organization. Research organizations have not had in the past and will not have in the future a monopoly on sources of new ideas and improvements. But the autonomous research organization has repeatedly shown itself to be

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This chapter by C. C. Furnas, Director, Cornell Aeronautical Laboratory.

the best mechanism for harnessing, directing, and co-ordinating those human activities which lead to the acquisition of new knowledge and the invention of new things. Research and invention steadily become more complicated—not less—and call for an increasing efficiency in the application of highly specialized skills and scientific knowledge. For the future, there is every indication that organized research will acquire increasing importance as an instrument of industrial survival.

A Definition of Research

Research, like poetry, cannot be defined in a manner that is universally acceptable. There is fairly good agreement, however, that research is the observation and study of the laws and phenomena of nature and/or the application of these findings to new devices, materials, or processes, or to the improvement of those which already exist.

The Objectives of Industrial Research

An industrial research laboratory is presumably a pragmatic organization. Its objectives are in some way directly connected with the future welfare of the particular company which supports it, particularly in regard to ultimate profits. But to achieve this end a list of objectives must be sufficiently specific to serve as the basis for planning a research program.

Opinions on specific objectives, when obtained from various sources, will probably be as divergent as opinions on new spring fashions. With a certain degree of temerity, then, the author suggests that the principal objectives of industrial research are:

1. To improve the quality of products.
2. To develop new materials, processes, or devices for existing or new markets.
3. To develop new uses for existing materials, processes, or devices.
4. To effect savings in cost.
5. To abate dangers or nuisances.
6. To prevent or cure troubles of production or use.
7. To assist in standardization.
8. To improve customer and public relations.

The Pattern of Industrial Research

The broad pattern of industrial research is clear—a diligent search for a preconceived end result. But the course to be pursued, like

Odysseus' journey, may be long and devious, with many side trips. The Wright brothers planned to build a flying machine that would carry a man. They were ultimately successful but before they could achieve their goal they had to build and use a wind tunnel to determine the fundamental characteristics of airfoils, explore the intricacies of stability and control in flight by means of gliders, and devise a light-weight power plant. The quest for synthetic rubber, which began over a generation ago, led into many new fields of organic and physical chemistry and new procedures in chemical engineering, before even partial success was attained.

Industrial research management usually prides itself on being "practical," which of course it must be, but this practicality must embrace flexibility, imagination, versatility, and often an infinite capacity for long suffering. The answers to new problems are not obvious; if they were, someone else would have found them. The most effective applied research organizations are those which are prepared to acquire and use all available knowledge which is applicable to the new problem. If the available knowledge is inadequate, they are also prepared to supply new knowledge. At times this will call for fundamental and exploratory research, development activities, and close co-ordination with production problems.

The interrelation of activities, from the discovery of a natural law to the manufacture of a product, may be presented as a flow diagram, as in Figure 1. This is not an organization chart. It is only a suggested diagram of the steps that may be considered to be involved in transforming a new concept to a practical reality in the form of a new product. Whether a formal organization is involved, or none at all; whether a thousand men are involved, or only one; whether the steps are taken consciously, or unconsciously; the divisions and gradations of activity are very much the same. The function of an industrial research laboratory is to supply the organization, motivation, talent, and facilities to secure optimum results.

Exploratory Research

Exploratory research is one of the most common of human activities. It may be approached from a background of great scientific knowledge or along the path of complete ignorance. It is the realm of the "try and see" or Edisonian approach. It may be pursued with or without preconceived objectives. In scope it ranges from a small boy dismembering an alarm clock, to DeForest tinkering with a three-element tube, to the more or less accidental discovery that the penicillin molds inhibit the growth of other organisms. It is the traditional realm of the inventor. It is the area where new items or improvements are conceived, carried through the gestation period, and properly born.

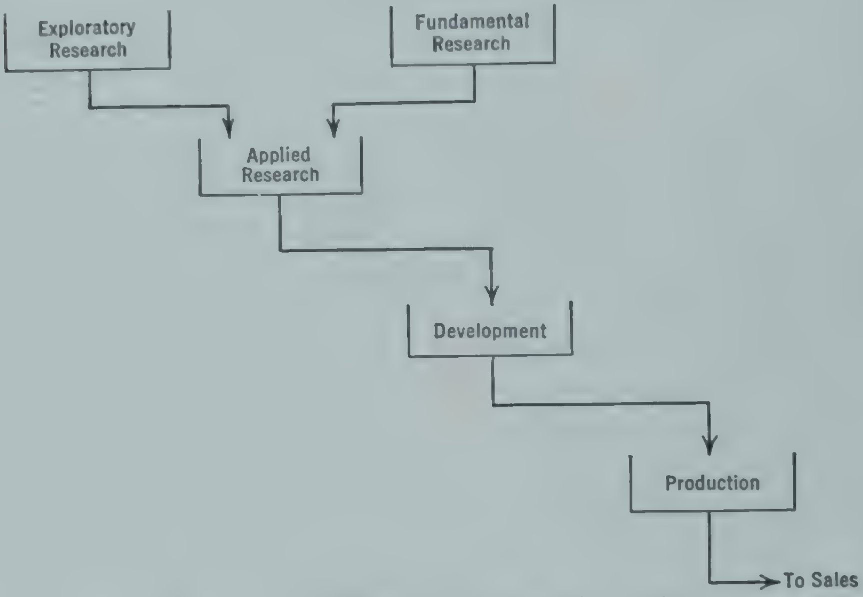

FIG. 1. Flow diagram: From research to sales.

Conceivably, an applied research laboratory could be maintained profitably by omniscient assignments from above, or by a flow of pressing problems from below, but experience has shown that applied research is a reservoir which can best be kept filled from the spring of exploratory research.

In the long run, a portion of a research organization's talents can most profitably be occupied with unhampered searching and researching without the restrictions of narrow task assignments, and with control that is light and unexacting. Many a very important product of industry today has come about because of the opportunity given or taken by some individuals to follow their bent of natural curiosity, to "try and see." Research laboratories have been devised to take organized advantage of the human propensity to explore; so it would appear to be short-sighted not to have this activity as a recognized part of the program.

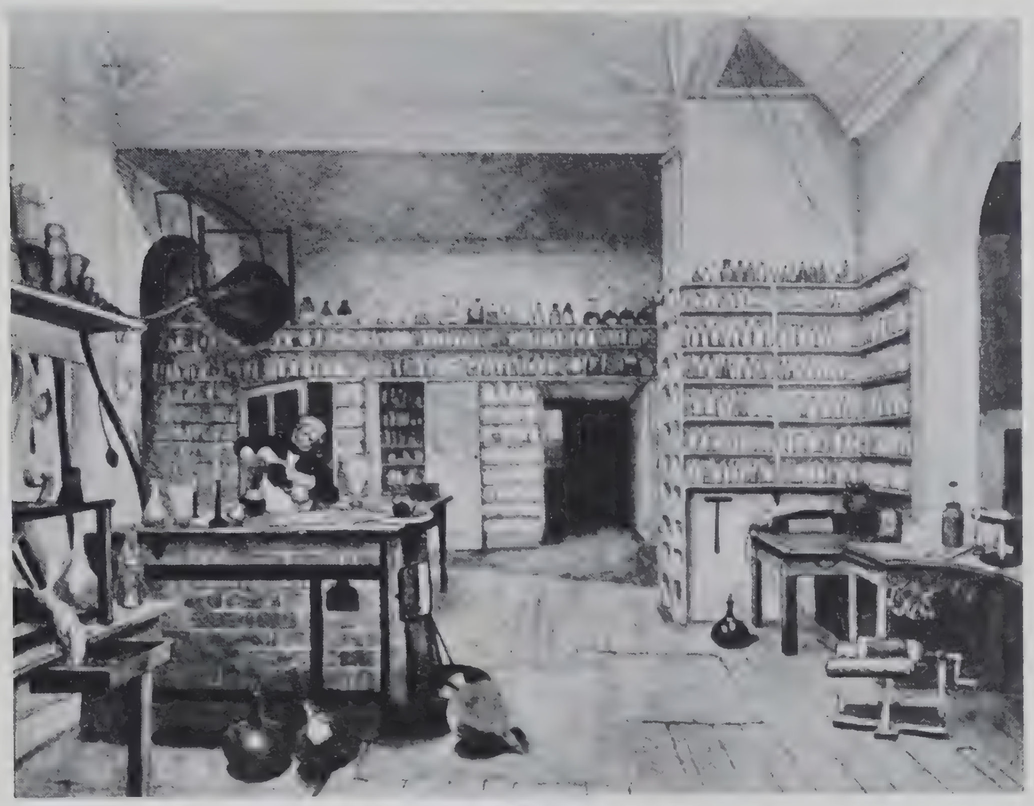

Photo. 1. The old and the new in research facilities. Faraday's laboratory. (*Courtesy Fisher Scientific Co.*)

Photo. 2. The old and the new in research facilities. The modern RCA laboratory at Princeton, N. J. (*Courtesy of the Radio Corporation of America.*)

Fundamental Research

Fundamental research is the investigation of the fundamental laws and phenomena of nature and the compilation and interpretation of information on their operation. Though exploratory research is usually considered essential to the well-rounded industrial research program, true fundamental research ordinarily assumes a minor role. This should not be construed as belittling the importance of a sound background of fundamental knowledge, but it is a fact that the sources are usually other than industrial research laboratories—universities, research foundations, and government laboratories. Though there is a slowly growing tendency for industrial organizations to take the initiative in discovering the intricacies of the laws of nature, they usually undertake fundamental research with an air of self-defense—only if the fundamental knowledge required on some problem cannot be obtained from some other source.

The soundness of this point of view is certainly debatable. In defense, it can be pointed out that an industrial organization must demonstrate from time to time that its operation is profitable, and fundamental research is notoriously slow in showing a profit. Further, the inventive mind, properly schooled in the presently available fund of scientific knowledge, can be, and usually is, very productive in the field of exploratory research, without delving into new fundamental research.

Balancing these points is the evidence from a few of the long-established industrial laboratories which have made significant contributions to fundamental science and have been able, profitably, to apply these findings to successful developments. There is also an increasing realization that the strength of research organizations is built around the quality of the men. Good scientists are a necessity for good laboratories. Many of the better scientists cannot be attracted to and held in industrial positions unless opportunities are afforded for bona fide fundamental research, often of their own initiation.

Our industrial civilization is rapidly becoming more involved and more scientific. As any field becomes more extensively explored, the fundamental scientist becomes more necessary. In the early days of research, the exploratory activities of an inventive but unscientific mind were sufficient to make rapid progress. That day is already past in many fields and rapidly passing in others. The fundamental scientist will become more important in industrial laboratories, and fundamental research, with time, will assume a more important role, but the change will probably not be rapid. Newly founded industrial research laboratories are probably well advised to approach fundamental research activities cautiously until the organization has had time to prove its worth to the omnipresent management. But any research organization that does not seriously plan to engage in a certain amount of fundamental research at as early a date as possible is probably not going to be in a position to grow to full stature. As corporations grow in size and diversify their activities, they arrive at a point where unexpected research results, which arise from a fundamental program, can be used to as good advantage, and hence are as valuable as those which can be accurately predicted.

Applied Research

Applied research is the pursuit of a planned program toward a definite practical objective—a preconceived end result. It takes the results of fundamental or exploratory research and tries to apply them to a specific process, material, or device. Exploratory research indicates that a certain result is possible. Applied research moves it from the realm of possibility to that of high probability. Although the boundaries of the different classes of the research function are only as exact and definitive as the hazy boundaries of an ocean current, applied research usually carries an investigation up to the point of the first successful working model of a mechanical or electrical device, or through the usual glassware stage in a chemical synthesis.

If exploratory research represents conception and birth of an infant, then applied research represents the period of childhood. The offspring starts rapid growth and begins to display definitive characteristics that can be evaluated with a fair degree of certainty.

If the different phases of research activity could be evaluated, the applied research phase would probably be the most important for those industrial laboratories where the emphasis is on new products or processes. It is the phase where nurture and guidance are most needed. A good idea can easily die for lack of inspiration or attention on the one hand, or can be smothered to death by excessive planning and tight scheduling on the other.

Development

Development is the period of adolescence in industrial research—the project grows up. It is primarily the bailiwick of the imaginative engineer, whereas the work in applied research usually requires the chemist, the physicist, or the metallurgist. From the technical point of view development might be defined as the application of technology to the improvement, testing, and evaluation of a process, material, or device resulting from applied research. In a still broader sense, however, development may logically include the market evaluation of a prospective product. Hence the following items may be listed as the parts of the complete development activity.

1. Engineering, production, and evaluation of service-test quantities (electrical or mechanical devices).
2. Design, construction, operation, and evaluation of product of pilot plants (process industries).
3. Service testing of materials, processes, or devices.
4. Application research, with prospective customers, on new devices, materials, or processes.
5. Market research and evaluation.

Though primary emphasis in an industrial research organization is usually on applied research, with due attention to fundamental and exploratory work, the development phase must be an integral part of the over-all planning. Obviously it may not always be desirable to place the responsibility for all of these development functions with a research organization. They may be divided up in many ways throughout a corporate structure, but co-ordinated planning and execution are definitely beneficial.

Experience has shown that a good development man does not make the best research man, and vice versa. Hence, in the larger organizations, the line of authority and responsibility for development is normally separate from that of the research laboratory, though both frequently report to a common head. Though it often proves painful to separate the maturing child from the parent who has reared it through the applied research phase, possibly even from the exploratory stage, it usually turns out to be a necessary operation.

The evaluation phase of development denotes far more than might be apparent on first thought. Evaluation often means extensive engineering testing. It implies the formulation of controls and standards for anticipated production. It often involves extensive testing and evaluation in the environment of the ultimate user. The development engineer may have to spend major blocks of time in a production plant to insure that a new process or gadget is going to work as conceived and intended.

Two commonly accepted household items, the present hand-set telephone and nylon hosiery, became rather famous because of the long and thorough field-testing and evaluation program which was pursued before they were offered to the public at large. Thousands of the hand-set telephones and thousands of pairs of nylon hose were judiciously placed with typical users and test results and customer reaction were assiduously studied. Improvements were made and the evaluations repeated. Before production for the mass market was ever started the respective organizations were certain that they had a good product that the public would accept enthusiastically.

In the aircraft industry, the development phase of research is represented by the experimental airplane—usually full scale. Unfortunately you cannot approach flying in small increments—it has to be all or nothing. Either an airplane flies or it doesn't; there is no in-between. Great care, therefore, must be exercised in the engineering and construction of the test prototype. If the test airplane does fly, the evaluation consists of extensive test flights for aerodynamic characteristics and performance. The findings usually lead to extensive modifications, sometimes to a complete redesign.

Though the activities described above carry one far beyond the walls of any research building, they are, in the broadest sense of the word, part of the industrial research pattern.

It is obvious that development, as described above, can be a very expensive operation. It is quite likely that several million dollars were spent on the nylon project before a pair of nylon stockings appeared in a department store. A very ordinary commercial or military experimental airplane calls for the investment of five to ten million dollars, before it ever takes off. In the process industries, there seems to be a general rule that development costs are five to six times the applied research costs. Such statements are made without any exact definition of the dividing line between applied research and development, but they are indicative of the relative magnitude of the effort expended in the two activities.

The general public, and many engineers, apparently have little concept of the great span of time required to bring a research idea to the point of being a useful product. A long period of gestation is required, usually about five years, but often longer. It is perhaps significant that in World War II not a single American combat airplane was in use at the end of the war that had not been conceived and had its design begun before the beginning of the war. The Germans began serious work on their V-2 missiles in 1933. They were first used in warfare in 1944. The basic facts about uranium disintegration were known in 1939. The first atomic bomb was not dropped until 1945, despite the fact that two billion dollars and several hundred thousand man-years of human effort had been expended in its development. Like certain processes of nature, the development of a new product apparently cannot be hurried beyond a certain fixed point.

Production Research

In the production phase, the research child grows to full maturity. Not until it arrives at that point can it be said to have started on a useful industrial career.

Even after a new item has arrived at the production stage it still has, or should have, some ties with the research organization. The desirability of the guiding hand of the development engineer in the early stages of production is fairly obvious.

Moreover, a good production organization is never static. It keeps changing. If the production unit is successful, the changes are improvements. But changes always bring difficulties, if not troubles. Thus the research laboratory plays a logical, continuing role of production research in the production picture.

Production research activities normally fall into three classifications:

1. Investigation of new production methods.
2. Investigation of methods of standardization and control.
3. Specialized "trouble shooting."

The production organization, with its requirement for exact control and its emphasis on immediate results, calls for different talents and a different psychology from those which are most applicable to applied research or development. A production organization seldom provides an appropriate environment for the direct supervision of a research organization. Research work on production problems, however, may be very beneficial. Though sometimes difficult to achieve, there should be careful co-ordination and co-operation between the two activities.

Adequate contact between plant and research laboratory often has a very beneficial converse effect. The production man's frequent criticism that research men are too academic and impractical is often sound. One of the most effective ways to keep a research organization properly in touch with reality is to have a significant proportion of its efforts focused on the problems of a production plant. But such a program has its dangers. If a research organization is willing and able, a production plant may call for a disproportionate amount of its efforts and thus stifle research. Or the emphasis on the "practical" problems of production may be so great that the research laboratory staff may lose its vision and cease to be a vital force in investigating that which is new. Moderation is definitely the watchword for the collaborative efforts of research and production but, if geographical location permits, such joint activities are often found to be highly desirable.

The many facets of the problem of laboratory location and desirable degree of collaboration with production activities will be discussed in detail in later chapters.

The Problems of Planning

The multiple objectives and the several paths of activity discussed above make it evident that industrial research is not something to be entered into lightly. To a person planning on entering the field, or on evaluating an existing organization, many broad questions readily come to mind.

> How much should a given organization spend on research per year?
> How can the productiveness of a research organization be evaluated?
> What facilities should be provided, and where?
> What is the best patent policy to adopt?
> What is the proper pattern of public relations in connection with research?
> What type of research organization is most desirable, and where should it be placed in the corporate structure?
> What are the particular and peculiar personnel problems associated with a research organization?

These questions are by no means unique with research. Similar ones could appropriately be asked in connection with any contemplated or existing production organization. But it is almost a foregone conclusion that the proper answers will not be the same for both cases. The answers are probably more difficult to obtain for the research case, because the situations are more complex than they are for production, and research is the newer activity in which experience is more limited. It is logical to assume that, as the body of experience in industrial research is enlarged, the best answers to some of the above questions will become more clear. But they will never become standardized. Research, if successful, inevitably leads to change, and change is the antithesis of standardization.

The chapters which follow reveal the experiences of a number of the nation's leaders of industrial research, in answering questions such as those above. These expositions show few signs of fixity or standardization. One theme, however, recurs with sufficient frequency to attract particular attention—the necessity for autonomy of the research organization. Parallel to this, or perhaps as a corollary, is the repeated emphasis on the necessity of respecting the inherent individuality of the research scientist. These requirements, if such they are, when fitted into the traditional industrial pattern can lead to some difficult and often paradoxical situations.

The Horns of a Dilemma

Industrial organizations, by their very nature, can have but relatively little room for the exercise of extreme individuality. But if individuality of organization and person is required for successful research—as seems to be the observation of those experienced in the field—how can it be fitted into the necessary framework of a strictly industrial organization? This is a dilemma that is never eliminated, and only seldom satisfactorily resolved. Nevertheless, satisfactory compromise solutions can be found, as is evidenced by the continuing high degree of success of many industrial research organizations.

The analogy between adequate organizational co-operation and athletic team play has been sadly overworked, but it is still apt. The secret of the success of an industrial research laboratory *is* team play, smoothly executed by a group of competent persons. The often-emphasized individuality of research men and organizations is not primarily due to any abnormal desire to appear unusual or precious, but rather to a recognition that research is always new, and the detailed planning and execution can be carried out properly only by the person or organization which is responsible for results. A horse which is hobbled cannot travel well or far.

The Role of Research in Industrial Planning

Though a research laboratory often starts as a minor activity in a back room, or relegated to a mere service function, it eventually rises in stature and in its position on the organization chart. This is its history in the most successful companies where research has arrived at the point of being responsible not only for certain technical matters but also for certain phases of over-all company planning.

An analysis of its function and its possible impacts on the industrial pattern readily shows that research is one of the essential partners of the planning team, whether or not it is so recognized organizationally. The listing of a few specific questions will indicate the reason.

Should the research laboratory devote all, or the major portion, of its attention to (1) developing new products or processes, (2) improving quality of the present products, or (3) lowering production costs? Or should it spread its efforts equally among all three categories? Obviously, there is no pat answer to these queries. The answers can only be found by a careful exploration into a complicated matrix of business and technical facts and ideas. The director of research is the only one in the proper position to give reasonably valid estimates on the expenditures of time and money required to made adequate progress on a particular problem in one of those three categories. He also should have valid opinions on the possible technical impact of success. Engineering, production, sales, and financial aspects are obviously of equal importance in laying out a major program. The representatives of all branches are necessary to make a complete planning team.

After emphasis in a field of activity is agreed upon, shall a particular problem be attacked by "practical" (often called "quick and dirty") methods, or should an exploratory and fundamental research program be pursued? A director of research is supposed to be prescient enough to give a partial answer, though by no means a complete one. He will be influenced primarily by technical pros and cons which need to be balanced by economic aspects.

After a specific program is agreed upon, shall a rush program or a leisurely attack be pursued? A rush program usually leads to mistakes which must be expensively corrected, but often it can save time. Which, in a given instance, is more important—time or money? Joint consideration by the representatives of the various divisions would seem to be indicated.

To present any precise rules, or even a fixed philosophy, for arriving at the optimum answers to the above questions would be to indicate a unanimity of opinion that does not exist among research executives. The experiences and opinions of these men can serve well, however, in enriching the background of those who are interested in seeking answers to their present or anticipated problems in the organization and management of industrial research.

CHAPTER II

The Research Laboratory as an Operating Department of the Company

In the preceding pages research has been defined as the systematic exploration of the realm of the unknown to find satisfying answers to the questions, *what, how,* and *why.* It has been indicated that when these questions relate to industrial products or processes, research becomes industrial research. Its more particular objectives then become the improvement in these products or processes, or the development of new and better ones. In achieving these particular objectives, it generally follows that industrial research also adds importantly to our store of available fundamental scientific data.

To attain its primary objectives—that is, to improve products and processes or to develop new and better ones—the industrial research organization must be thoroughly conversant with the nature of these products, their conditions of manufacture and sale, and with all the problems connected therewith. Manufacturing and sales, in turn, must be fully conversant with the progress of research and development and must be in a position effectively to advise, assist, and take proper advantage of completed developments. Such a two-way intimacy can be achieved only if research becomes a full-fledged partner in the whole enterprise. The industrial research laboratory must assume its proper relationship in the industrial organization concerned, must become a recognized member of a team. The research department must recognize, and manufacturing, sales, management, labor, and the stockholders must recognize, that it is the job of research to see to it that there is a satisfactory product that manufacturing can produce and that sales can sell at a profit, so that man-

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This chapter by Charles S. Venable, Director of Chemical Research, American Viscose Corp.

agement can continue to manage, labor continue to work, and the stockholders continue to hold and profit by the company's stocks.

As an operating department, research—and management as well—must appreciate that certain broad generalizations or policies applicable to all operating departments must apply to research. These policies are designed to promote teamwork, are based on sound business experience, and should act not to inhibit but to catalyze research activity, not to dim but to brighten research enthusiasm. Their application to research simply insures an equality of treatment consistent with the real function of research and its highly specialized personnel, which in turn leads to the mutual understanding and confidence necessary before teamwork is possible. Realizing these facts, research can, and must, mold its personnel, equipment, and activities into a vitalized unit that fits snugly into the framework of the company, and that vibrates in unison with the other operating departments.

Accordingly, it is quite proper that any book on the organization and management of industrial research, such as the present one, should devote entire chapters to such topics as the place of the research department in the corporate structure, location of the research laboratory, public relations and the research department, translating research results into new products and processes, and other phases of research management that are intimately associated with the operations of other departments such as production, engineering, sales, and accounting. These detailed discussions, based on the extensive experience gained by many key organizations, should be of great assistance to those seeking to establish or maintain an optimum research arrangement to meet a given industrial setting.

In the present chapter, which deals only with the broad relationship of research as an operating department of the company, an attempt will be made to outline certain basic policies that must be observed if research is to function successfully in this operational setting. Various procedures have been devised to effectuate these policies, procedures that necessarily have been shaped by individual circumstances and conditions. These procedures will be developed in later chapters, when the various phases of research management are being discussed in detail. At the present point, we shall simply postulate a few "musts" that are basic for team play.

1. In the first place, as an effective operating department, *research should be on an equal footing in the corporate structure with other operating departments.* The director of research, it is generally agreed, should report directly to the same official, preferably the president, or to the same executive body, as the other operating departments, particularly production and sales. Under any other arrangement research becomes a service department and not a full partner in the enterprise. It is universal experience that research does not flourish in a climate of dependency.

2. It follows naturally that *research should be properly represented in the high councils of the company.* The direct representation of research on the board of directors is practically universal today with forward-looking and progressive companies. Also, production, sales, and research should talk together with management about the company's business. Various devices in research management have been designed to promote this co-operation. For example, one of the most effective devices used by the more successful companies, as a detail examination of their organization charts will demonstrate, is a research committee or research advisory council (other titles are used) where production, sales, and engineering are heard, and are in turn kept aware of the status of all important research and development projects.

3. In addition to a healthy relationship with the other operating departments, it goes without saying that the research department must be healthy within itself. *Research administration must deserve the respect of its partner departments, by commanding the confidence and support of its own personnel.* Its internal administration and organization must be on the effective and businesslike basis demanded of all operating departments. The line of authority and the line of technical supervision should be carefully established and made evident to all. It should be made plain, however, that the obvious purpose is to enhance research teamwork, and not to forge a rigid research assembly line that would choke off all individual effort and enthusiasm.

It is highly significant that this volume contains *six chapters on research personnel*, the heart and soul of the thing we call research. No research organization—or any other organization for that matter—is stronger than the men who compose it. These six chapters dealing with the training, selection, personal characteristics, inhibitions, professional growth, and proper handling of research personnel, are not placed first in the book, in accord with their importance, nor last in the book, by way of climax. They are placed in the center, where all good hearts are found, and where our souls are said to be.

4. As an operating department, *research should yield the maximum return for the money spent.* As shown in a later chapter, labor costs in a research department are abnormally high, averaging from 60 to 70 per cent of the total expenditure on research. Accordingly, it is only good business to strive for the highest yield from this major item of expense. Adequate supply of plant and equipment is simply a matter of sound economics. Right planning also suggests the use of a maximum of inexpensive personnel to increase the productivity of the more expensive. As will be shown in later chapters, careful thought and planning in these directions is a primary duty of research management.

5. If the research department is located in the neighborhood of the manufacturing department it has generally been found that good relations, as well as the highest degree of research efficiency, are furthered by *having the research department fairly well self-contained.* For example, plant engineering should not be bothered by requests for service from research, nor should research be forced into hopeless competition with the service calls of manufacturing. Only frayed tempers and loss of a healthy mutual interest can result. In these and in other similar respects, research should be equipped to take care of its own needs as far as possible, even at the apparent expense of considerable duplication.

6. It is generally agreed that *the research program should be the personal responsibility of research management.* As an operating department, research should be charged with the charting of its own course, but this course should be integrated with that of the entire convoy. The importance of mutual co-operation in this respect has already been stressed.

With this intimate participation of research in the affairs of the industrial family, however, it becomes highly important that the true function of research be adhered to without compromise. Research is to improve, develop, invent, and is not to control or remedy routine operations. Like other human organisms, research cannot serve two masters. Experience is universal that it is fatal either to research or to plant control—or generally to both—to place responsibility for both functions in one department.

More often than not, research laboratories are located in close proximity to manufacturing plants with the deliberate intent of giving research personnel physical contact with the spirit and with the difficulties of manufacturing, and vice versa. Under such circumstances, adequate precautions must be taken that the fundamental objectives of research are not smothered by the all too visible urgency of manufacturing problems. This proximity is considered especially useful where the nature of the business requires that pilot-plant operation follow closely upon the heels of laboratory development. Where proximity is not practical or advisable, various devices are used to bring key personnel together periodically for a man-to-man exchange of information and ideas, something unobtainable through the impersonal medium of written reports.

7. As an operating department, *research should pull its own weight in the financial boat.* Since the products of research are usually "sold" to the company itself, it is helpful if some form of evaluation or credit can be set up for completed research projects, and an accounting arranged between this calculated "income" and known research expenditures or outgo. Where such arrangements are practical, research budgets can be more intelligently planned and research appropriations "earned." Succeeding chapters will cover various procedures in detail, and many systems will be cited that are now in successful operation.

It is often found, however, that a strict accounting for research is not possible. A fair yardstick for "income" for the research member of the industrial team is sometimes difficult to establish. For example, it is generally impractical to attempt to set up a reasonable credit for improvement in quality of a product. In addition, it is sometimes difficult to evaluate "work in process" in a research department. In such cases, management must make due allowances when book credits for research fall below or currently exceed actual debits. In the last analysis, if the company continues to make a profit in the face of competition, the research department for that company must be operating at a profit.

The research accounting system perhaps finds its greatest general value in indicating the lines of maximum probable profit. For example, the figure obtained by multiplying the estimated profit to be gained by the probability of attainment and dividing by the estimated cost, can often determine whether a given research project should be undertaken, or, in case of review, whether it should be continued. Some such system can also be utilized to determine a forced choice between projects.

Thus, with an adequately staffed, equipped, and inspired research group, nicely integrated to management and the other partner departments, and fully conscious of the true responsibilities in the enterprise, the fundamentals are correct for the effective operation of research in an industrial organization. The succeeding pages, based on the experience of many, are to give detail to that picture.

CHAPTER III

Development

Development is defined and handled differently in different companies and different industries, but in all of them the fundamental purpose is the same. Whereas research begins with a nebulous idea which has possible value and carries it to the point where the value seems probable, instead of merely possible, development carries the idea one step further. It continues the work from the stage of probable value to the stage of assured business. Development is simply an extension of research, but it is so different from much of the initial research and has so many special techniques of its own that it requires separate consideration. Research in the narrower sense is generally considered to stop when the work outgrows the laboratory workbench. What happens after that is development.

It is in the development phase that the research item begins to grow up, not only in size, but frequently in complexity. For mechanical and electrical devices this usually calls for designing, making, and evaluating a number of full-scale working models. Considerable emphasis is placed on specifications and on design criteria which will be realistic and usable in the final production engineering which leads to full-scale manufacture.

An analogous situation holds for the chemical industry, though the details of the technical work throughout the development phase will be quite different. The objectives, and the problems of planning, of execution, and of co-ordination with research and ultimate production are quite similar for all industries. Hence the examples dealing with the chemical industry, which are discussed in this chapter, can serve to illustrate the main features of development activities.

This chapter by J. K. Roberts, General Manager of Research, Standard Oil Co. (Indiana), and Edward L. Gordy, Assistant to General Manager of Research, Standard Oil Co. (Indiana).

The principal steps, several of which may be carried out simultaneously, are as follows:

1. Pilot-scale work.
2. Product evaluation.
3. Utilization studies.
4. Economic studies.
5. Process design.
6. Market research.
7. Market development.

Pilot Plant Work

An increase in size of operation frequently makes a chemical reaction harder to handle. Where heating or cooling are involved, difficulties arise from the fact that large quantities of material cannot be heated or cooled as readily and quickly as small quantities. Large vessels have less surface per gallon of contents than small vessels. Although reactors can be designed in shapes which minimize the effects of this inconvenient relationship, and heat exchangers are a great help, it is seldom possible to have surface keep up with volume.

The pioneers who worked on oil cracking found that in the laboratory it was fairly easy to crack the oil by heating it under pressure. When they went on to use large vessels, however, they had to drive much more heat into the oil per square inch of heating surface, and this increased severity of heating rendered the metal of the still bottoms less able to stand the required high pressures. Furthermore, in the course of the cracking reaction, coke was formed and was deposited on the bottom of the stills, where it acted as an insulating layer and retarded the transfer of heat. This difficulty was obviously increased when each square inch of still bottom began receiving coke from a seven-foot layer of oil above it instead of from the few inches of oil present in the laboratory vessel. Oil cracking therefore became possible on a commercial scale only after extensive work had led to knowledge of the conditions which minimized the amount of coke formed.

The difficulty of cooling large vessels becomes especially troublesome when the reaction is one which must be stopped at a particular point. In the making of certain soft alkyd resins, care must be exercised to keep the reaction mixture from setting to a rubbery mass, which is not only useless as a product but is also extremely difficult to remove from the reaction vessel. This problem was solved by development work which established with great accuracy the amount of heat required. The reaction is carried most of the way to completion by raising it to a high initial temperature, and is then allowed to complete itself while the temperature is gradually falling to a harmless level.

Trouble is also caused by the fact that reagents cannot be pumped into large tanks as quickly as laboratory beakers can be emptied into one another. Addition of reactants requires special study in cases where the temporary presence of a large excess of one reagent may have a substantial effect on the course which the reaction takes. Particularly where pH is important, rapid adjustment on a large scale may be difficult. The methods available for making large-scale transfers of material may themselves introduce complications. A method for separating two similar organic materials by fractional crystallization proved easily operable in the laboratory but ran into difficulties in the plant, where rotary pumps broke the crystals into a fine, practically amorphous mass that clogged the filters.

One of the important factors in carrying out chemical reactions is the rate of agitation. It always influences the speed of reaction, and may influence the course the reaction takes. In making organic peroxides by adding acid chlorides to a chilled solution of sodium peroxide, the acid chlorides prefer to react with the sodium peroxide but will also react with the water. It is therefore desirable to keep the acid chloride moving rapidly into new areas, where the sodium peroxide has not been used up.

Agitation is a factor which is difficult to measure, and one which is apt to vary greatly as the size of the equipment is increased. Generally, agitation in a laboratory flask has a far greater intensity than is feasible in the plant. Thorough testing of agitation effects is therefore necessary.

Plant equipment is also usually less susceptible to accurate measurement than laboratory equipment. Few plant tanks are equipped with weighing devices. The contents must be measured by gauging, which, at best, is inaccurate. Where proportions are highly critical, the commercial plant must sometimes use an entirely revised procedure. A small-volume critical material may be diluted with one of the less critical large-volume ingredients to permit accurate measuring of the small-volume ingredient by plant measuring devices.

While the plant is usually at a disadvantage compared with the laboratory, it should be mentioned that in some cases operations are more feasible on a large scale than on a small scale—for example, operations which are critical as to only two dimensions. It is sometimes an advantage that volume increases more rapidly than surface as the size of the vessel increases. Where liquid phases must be separated, and there is trouble with emulsions at the interface, it may be possible to carry out a large-scale operation which is not at all feasible on a small scale. A large settler is more efficient than a small settler. Further, some counting advantages may be gained from the fact that large equipment lends itself somewhat more readily to operation under pressure. High-pressure operation permits higher temperatures to be used, and the resulting decrease in viscosity reduces the tendency to form emulsions.

Most of these problems involved in going to larger units may be said to be due to the vagaries of the "scale effect." Though the degree of unpredictability with increase of size may be greater in the chemical industry, it is still a major bugaboo in other fields. In the development of aircraft a great deal of preliminary aerodynamic information is obtained on small models in wind tunnels. This is followed by careful design and building of an experimental airplane which always has many unknown characteristics. By careful study of this experimental craft in flight, sufficient data can be obtained to proceed with confidence on the final design.

Large electric motors offer similar problems. Increases in size or in loading have to be approached in reasonable increments and with considerable experimentation. As engineering knowledge in any field advances, it becomes possible to design with increasing confidence to the next higher increment of size, speed, or temperature, but that necessary knowledge is acquired only by a careful tie-in of sound theory with extensive experimentation. In the chemical industry it has been found that the best way to guide the engineer in his steps into the next increment of the unknown is to design, build, and operate a pilot plant. Although pilot plants have certain other uses, their principal job is to confirm results of the research and obtain chemical engineering data needed for constructing large-scale equipment.

In the pilot plant the reaction conditions—pressure, temperature, rate of agitation, space velocity, and other factors—are established.

Usually the pilot plants permit considerably more study of corrosion and erosion than can be determined in bench-scale equipment, which is likely to be built of glass. Although the pilot plant work cannot definitely solve all the problems connected with an increase in size, it gives the necessary points on curves which can be extrapolated to plant conditions. It is in the pilot plant also that the many changes necessary in going from batch to continuous operation are usually worked out.

Scale of Operation

The scale of the pilot plant work may vary over wide limits. Research work is usually sharply limited by the size of laboratory glassware, and seldom involves more than four or five pounds of materials. Pilot plants, usually fabricated of metal, are less limited. Some of them may manufacture thousands of pounds of product a day. Where the process being investigated is simply a treating process, such as water purification or the desalting of crude oil, the throughput may be even larger, but the cost and size of the equipment do not enlarge correspondingly.

A Typical Pilot Plant Study

The types of data obtained in pilot plant studies will vary, depending on which factors are critical in each instance. Pilot plant work carried out on fluid catalytic cracking is a good example of the many functions which this work performs. In catalytic cracking, petroleum oils boiling above the gasoline range are processed with a finely divided solid catalyst at high temperature and near atmospheric pressure to give relatively large yields of motor gasoline. The catalyst, a natural or synthetic silico-alumina material, becomes coated with coke during the reaction, and this coke must be burned off in order to restore the catalyst activity. The solid catalyst is circulated between a reactor and a regenerator much as if it were a liquid.

Construction of a fluid catalytic pilot plant was based on a study, in glass models, of the behavior of powdered catalysts under the conditions which might be expected to occur in the proposed plant. After the pilot plant was built, a considerable amount of work was necessary to eliminate mechanical troubles and assure operation sufficiently continuous in nature to permit reliable data to be obtained.

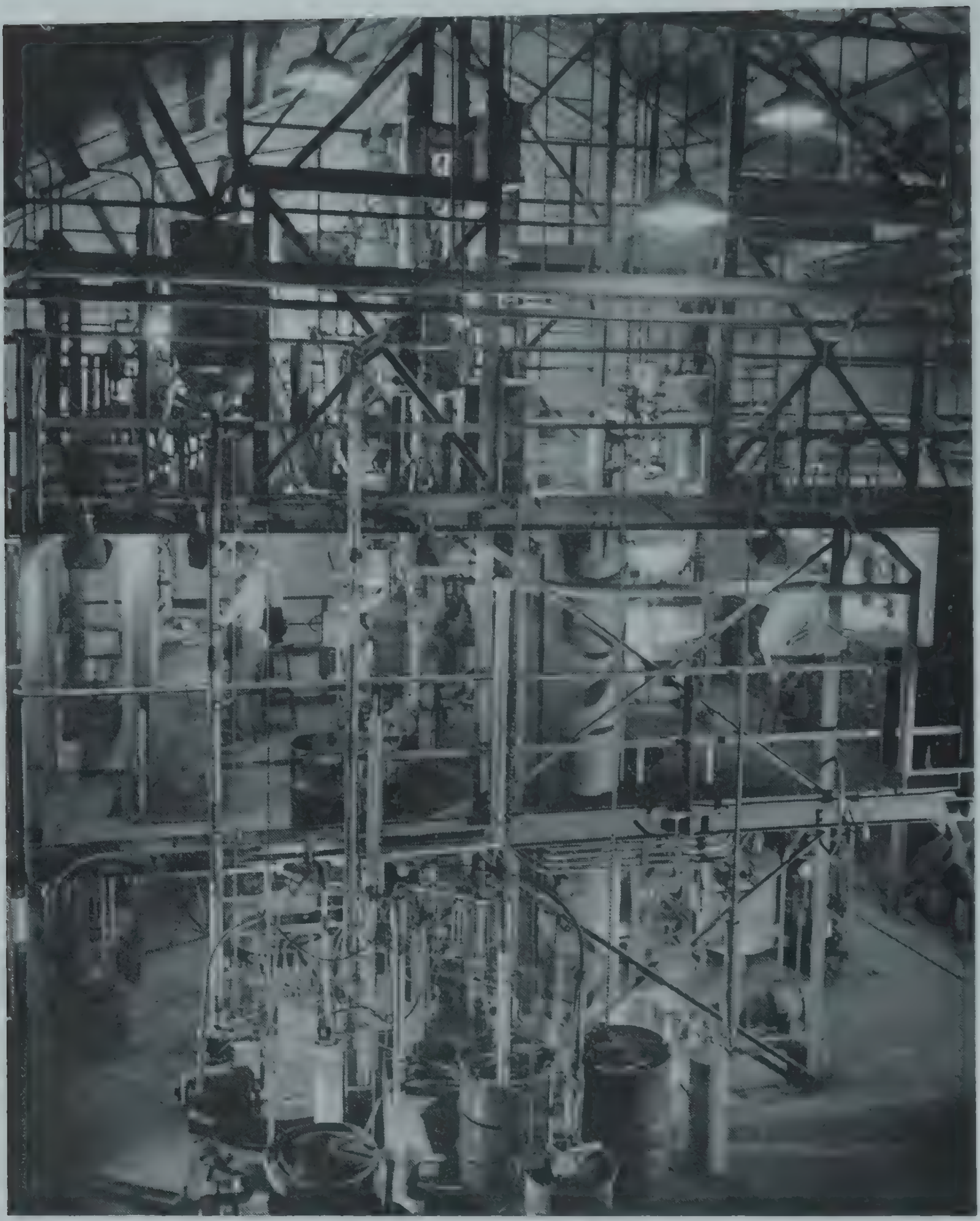

PHOTO. 3. Fluid catalytic cracking plant. (*Courtesy of Standard Oil Company of Indiana.*)

It was hard to keep the catalyst flowing freely in a properly aerated state. Attrition produced large quantities of fines, which detracted from the flow characteristics. In addition, systems for recovering the catalyst had to be more foolproof than the cyclone separators planned for commercial units. Filters of glass cloth and metal cloth were tried out before the final ceramic filters were developed. It was also necessary to work out suitable devices for regulating the flow of catalyst from the regenerator to the reactor and return.

When a mechanically operative pilot plant had finally been developed, it was used to study the fluid catalytic cracking process. The data revealed that a number of effects not previously considered significant had a large effect on the catalyst. For example, the presence of iron, from scale in the carbon-steel pilot plant, seemed to increase the amount of coke formed in the cracking reaction. Since the coke encouraged the formation of more coke, it became necessary to develop controls for regenerator operation, so as to give a relatively constant carbon content on the regenerated catalyst.

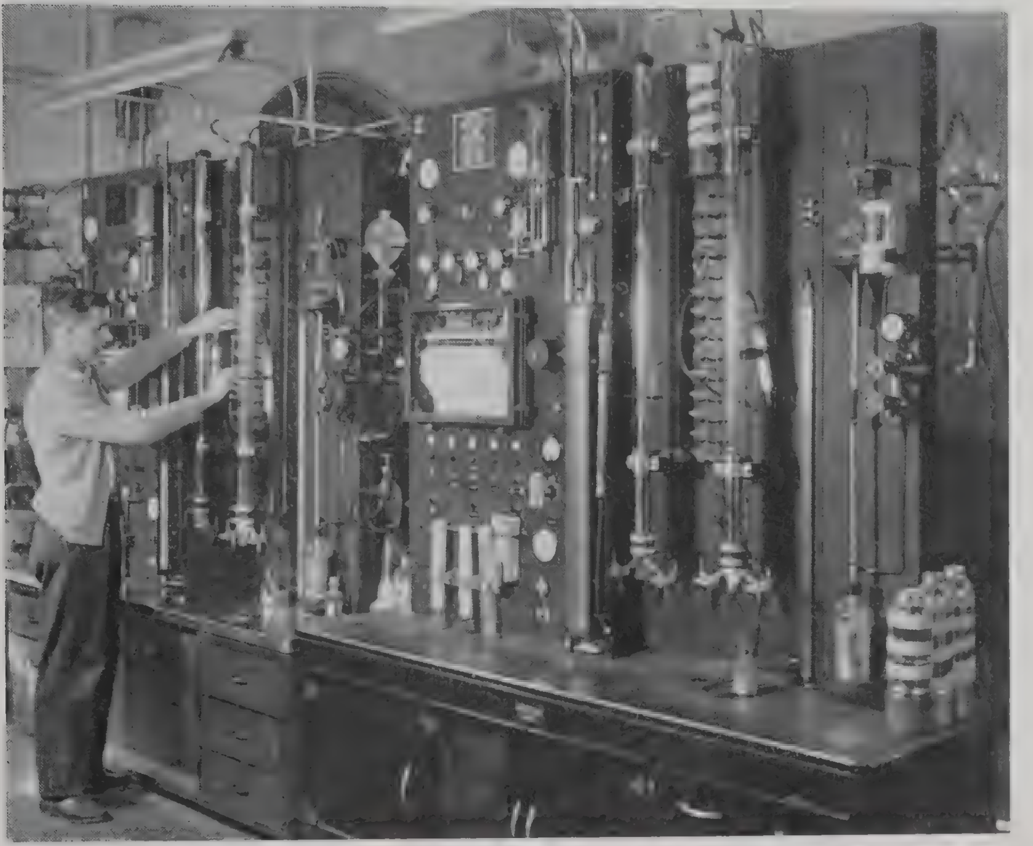

PHOTO. 4. Hydrobot fractional distillation units for analysis of hydrocarbons. (*Courtesy of the Standard Oil Company of Indiana.*)

Decline of catalyst activity with use had to be studied carefully, since this factor affected all the results. Effect of variations in the stocks to be cracked also had to be determined.

It was deemed desirable to go from a two-barrel per day pilot plant to a semi-commercial unit of approximately 100 barrel daily capacity, in order to provide more accurate engineering data for use in the design of commercial units. Among the factors studied in detail were the following: variables affecting the physical condition of the catalyst in the lines between the reactor and regenerator; heat transfer coefficients for coils in the catalyst bed and for catalyst flowing through heat exchangers; catalyst flow characteristics; means of measuring catalyst flow; slide-valve design; instrumentation; the effect of increasing the height and diameter of the reactor; effect of various reactor temperatures; erosive effect of catalyst on various materials of construction; effect of variations in catalyst circulation rates; and numerous other engineering points.

In all this work there was, of course, constant study of the yields and quality of the products of the cracking reaction: percentages of gas, gasoline, higher boiling liquid, and coke. The gasolines produced were evaluated in regard to octane number and all the other characteristics that must be determined for motor and aviation gasolines.

The success of the pilot plant programs in fluid catalyst cracking is attested by the fact that a large number of commercial units were built and placed in operation during the war with a relatively small amount of difficulty. In most cases performance of the units was very close to expectations.

Training of Operators

Among the further development functions of pilot plants comes that of training operators for the eventual plant equipment. Such training is essential when the ultimate equipment is to be very large, and where an upset would lose large quantities of valuable material or might damage expensive units. Training of operators on pilot plants is also advisable in cases where the operation is hazardous to personnel, and where complete familiarity with the operation is therefore desirable in order to insure prompt employment of correct measures when an emergency arises. Processes involving dangerous materials such as anhydrous hydrofluoric acid should certainly not be carried to a large scale without a thorough program of operator training. The preliminary part of such training should usually be carried out with products other than the hazardous material.

In addition to establishing engineering data for subsequent process design and service to train operators, pilot plant work has a number of other functions. It is usually the method used to produce samples for the evaluation laboratory as well as samples for customer appraisal. In the case of products which may be used as research chemicals or for other small uses, such as perfumes, the pilot plant may actually be used to produce products for sale. This is also true where the product is an intermediate and where the customer himself must go through a development stage. A synthetic resin manufacturer, considering the use of azelaic acid instead of adipic or sebacic acid, might be a customer for pilot plant quantities of the new product. In such cases, however, fundamental practicability of the operation must have been pretty well assured. It must be known that there are no steps which will be impossible to carry out on a large scale.

Pilot Plant Sometimes Unnecessary

Under certain special conditions the pilot plant stage may be omitted from the development program. There is no need for pilot scale work if the laboratory experiments have shown that operating conditions are not critical and if the ingredients used are known to be non-corrosive, but it is well not to be overconfident on these points. During the war, it was assumed that distilled water would be the ideal material to put into the water containers of lifeboats. Actually, distilled water turned out to be too corrosive, and had to be slightly modified.

Reactions carried out at low temperature and at atmospheric pressure often can skip the pilot plant stage. Stated broadly, pilot plant work may be omitted when all necessary engineering data have been obtained from the research phase. Cost of the ultimate equipment is also a factor in deciding whether or not to carry out pilot plant work. If the equipment to be used is simply an open tank agitated by air, the cost may be low enough to justify building the equipment and altering it or even junking it if changes become necessary.

Pilot plant work may also be omitted if time is an important factor—for example, if the product is so critical that it must be made available as soon as possible. The tremendously expensive plants used in preparing fissionable materials for the atomic bomb were built from data obtained in laboratory work carried out on a microscopic scale. The plutonium used for obtaining some of the data was actually made in a cyclotron where it was produced in quantities of micrograms. Many of the wartime synthetic rubber plants were put into operation without what would normally be called adequate pilot plant study of the reactions, and the catalytic cracking units used in making aviation base stock were also engineered from less complete pilot plant data than would have been compiled in normal times.

A similar urgency may eliminate or reduce pilot plant work when it is desired to enter a field ahead of a competitor. Particularly in the petroleum business, where the large scale of the operations may enable one or two companies to supply the entire industrial need, so that additional units would be of submarginal utility, the field is likely to be left to the first few companies to enter it. A process, for example, for making salicylic acid from petroleum hydrocarbons would enable any one of the large oil companies to supply the country's entire demand, amounting to about six million pounds a year of this product. There would therefore be considerable incentive to be first in the field with such a process. The need for promptness in entering a field, however, should not entice a company into doing so little pilot plant work that a competitor will be enabled, through more extensive development studies, to render the first producer's plant obsolete.

Pilot plants, of course, do not go out of service when the commercial plant has been finished and is successfully operating. They continue to be used for evaluating catalyst and feed stocks, and for investigating possible changes in operation for the large units, but this work is technical service to manufacturing rather than primarily development work.

Utilization Studies

Utilization studies are most important in connection with entirely new products. When the laboratory produces a new material which looks as though it has commercial possibilities, the obvious next step is to determine such physical properties as specific gravity, viscosity, vapor pressure, boiling point, tensile strength, hardness, etc. Often there is some key property which at once awakens interest in the product. The work carried out on high polymers by Wallace

PHOTO. 5. Slip tester to test resistance to slippage. Empirical tests play an important role in development. *(Courtesy of the Monsanto Chemical Company.)*

PHOTO. 6. An empirical method of measuring abrasion resistance. *(Courtesy of the Monsanto Chemical Company.)*

H. Carothers in the Du Pont experimental laboratories was initially an exploration in pure science. It became of great practical interest, however, when Dr. Carothers found that threads of the new products possessed good tensile strength. Development of the remarkable textile fiber, nylon, resulted.

Empirical Tests

Tensile strength is a definite physical property which is easy to measure. In many cases, however, there are less well-defined physical properties which may be important to utility of the product. These might be designated "practical" properties. They include such things as oiliness, film strength, stringiness, tackiness, binding power, solvent properties, wetting power, etc. Some of these properties have been made the subject of empirical tests which indicate roughly whether or not the product is comparable with other products used for similar purpose. In many cases, however, there are no tests sufficiently well defined to be reproducible in different laboratories by different observers. While such qualities as the draping tendency of a textile fabric are gradually being brought into the range of laboratory tests, and while the scope of these tests is being extended, in many fields the tests are subject to idiosyncrasies of the observer. It must be admitted, however, that experts can check one another's results, even on tests which they cannot define. Those experienced in determining the "hand" or feel of a textile fabric seldom disagree, despite the fact that the property they are seeking varies in different fabrics; it is not merely softness but a special feel which the particular fabric ought to have.

In some fields there are no valid evaluation tests other than actual use. The petroleum industry recently learned that the tests used to examine the binding power of road oils became inoperative when West Texas crude was used as the starting material. It has been necessary to set up actual road sections and subject them to ordinary traffic in order to test the binding power of road oils. Binding power is a function of amount and type of unsaturation and this in turn measures polymerizing tendency, but no adequate laboratory means have as yet been found for measuring these tendencies and interpreting them in terms of field performance.

The petroleum industry has also been concerned with developing performance tests for lubricating greases to replace specifications

Photo. 7. Device to measure shrinkage of wool socks. Product testing is an important phase of development programs. (*Courtesy of the Monsanto Chemical Company.*)

based on composition. The new tests, which determine how the grease performs in the bearing, proved extremely valuable in meeting the wartime demand for greases. They permitted greatly increased flexibility in compounding and, since some of the new formulas gave improved performance over the old, the result was a higher quality of grease for military equipment. Performance tests are always a great assistance to development work and are well worth the time and money it takes to perfect them.

In addition to the physical properties of the new product, chemical properties must also be determined—stability, corrosiveness, and particularly the behavior in chemical reactions. In many cases, it is also necessary to prepare the most promising derivatives and then subject these products to physical tests and empirical utilization tests.

Establishing Uses

By all these devices, uses for the new product are sought. While it is unlikely that all of them can be found, enough must be discovered to justify erection of a commercial plant, and quite accurate data regarding the product must be obtained for advertising and publicity purposes.

Even in the case of products of established use, a good deal of utilization work must be done. Since the nature and amount of the impurities are frequently quite critical, comparison with competitive products must be carried out. There is often a substantial difference between the producer's idea of proved utility and the customer's idea. For this reason extended service testing is often required.

Utilization work probably represents the biggest job in introducing new products. Since it is not carried out by applying well-known, easily followed chemical reactions, it is time-consuming; compared with even other development work, it is expensive. The relationship between physical and chemical properties and use is frequently not clear, and there must be extensive work, either to clarify these relationships or to carry out cut-and-try work. Frequently the most efficient place to do this work is in the potential customer's laboratory, but here a number of difficulties are encountered. They begin with the customer's inertia and his unwillingness to carry out tests without a pretty fair assurance that they will be successful and will give him either savings or an improved product. There may also be other obstacles. In many industries there is an exaggerated fear of revealing trade secrets. The research director for a leading maker of dyestuff intermediates once said that his greatest problem in straightening out customer complaints was to get at the nature of the difficulty. The customer was afraid to discuss the trouble for fear of giving away secrets. In a number of these cases it happened that the intermediates manufacturer later bought up the dye makers. The carefully concealed process usually turned out to be one about which the intermediates manufacturer had forgotten more than the dye maker ever knew.

Troubles sometimes arise from a user's misconception as to what constitutes utility. Despite the fact that there are now accurate electronic instruments to measure detergency, and that detergency has been shown to bear little relation to sudsing, many laundry operators are unwilling to consider a detergent which does not produce copious suds. Barriers of this sort are encountered in all the fields which remain arts instead of sciences. In some fields, of which the textile industry is an example, the user may employ a product for reasons which have prevailed for generations and become traditional, the present generation not even knowing what the original reason was. The present operator uses the product because his grandfather did. So long as the operation is a success, there exists the not altogether unreasonable attitude that a winning game should never be changed.

Although it is probably not a major factor today, we should probably mention the fact that the development staff sometimes runs into cases where poor performance is due to ulterior motives on the part of the testing personnel. For years a particular dye was used on United States stamps because a bribed printer was spitting tobacco juice into all competitive dyes before putting them on the printing equipment.

Work by Outside Organizations

Utilization studies can sometimes be carried out most expeditiously by an agency which is neither producer nor consumer. Rough screening tests of the new low molecular weight alkanesulfonic acids developed by a petroleum company indicated that electroplating was a very promising field. Since it is a field which requires highly specialized knowledge, utilization studies were transferred to the Battelle Memorial Institute, which has had a long history of experience in electroplating. Consulting organizations are also often able to do a good job of product evaluation. Moreover, consultants and research institutes frequently have desirable contacts with consuming industries, and in the end some consumer testing is almost always necessary.

In addition to the development work which consists of trying to find uses for new products, it is profitable to hunt for needs and then try to develop products to meet them. The Carbide and Carbon Chemicals Corporation has probably had more experience than any other American company in developing uses for new products. In describing its work, George O. Curme, Jr.,[4] makes the following statement:

> On several occasions in my experience I have been in the position of having, as a result of research work done in my laboratory, a process for manufacturing a chemical product, never before available in commercial quantities. I considered it a part of our research program to find out what uses could be made of the new product so that its manufacture could be started on an appropriate scale, and also to indicate what prospective users should be solicited by our sales representatives. We always found some uses and users, but it has invariably turned out that the eventual large uses were other than those we had anticipated. This was a matter of great chagrin to me, especially after it had happened several times. Finally I consulted several friends who were directors of research of other companies and found that they had had the same experience. Now, assuming that we aren't all poor chemists, it seems that there is a generalization involved that is worth considering. It is this: The party with a problem to be solved, if he is chemically informed and therefore familiar with the requirements, is in the best position to evaluate the usefulness of a new product for his purpose; the party who has a new product on hand, but has no specialized knowledge of what uses need to be served, is in a disadvantageous position to find the best application of his material.

Dr. Curme concludes that "chemistry has been most successful in meeting the needs of non-technical users of chemical products when scientific research was applied to clearly understood requirements," as occurred during the two world wars, and he implies that seeking for needs first and then manufacturing products to fit them should be more widely used as part of the development process.

Relation Between Experimental Groups

The development work described thus far has been largely experimental. There must be a close relationship between the groups responsible for the various kinds of work. In a small company, where research and development overlap, there may not be separate groups. A project may be carried by the same people from the laboratory bench straight through pilot plant work and into actual production. In the absence of specialized groups whose expertness in their fields insures better work in each category, there are advantages to be gained by letting people who are familiar with the small-scale problems work on the problems connected with large-scale operation. A disadvantage is that the project becomes a pet of the group, who are inclined to magnify its importance in relation to other company activities.

In a large organization the dividing lines between the kinds of work are sharper, and care must be taken to insure good liaison between them. Generally speaking, the line of progress is from the laboratory research work to development work in the pilot plant and then back to the laboratory for the preliminary part of the utilization studies. Frequently the same group who did the original research will become a development group and carry out the bench-scale work on utilization. They are already familiar with the properties of the product and usually have done a good deal of thinking about possible uses.

As the utilization studies progress, and perhaps leave the organization altogether, it is an advantage to have them followed by a man who took part in both the original research work and the small-scale evaluation work. Each research group working on products for outside consumption should therefore have at least one man who is used to dealing with people and who can handle the sometimes difficult problems in human relations that may arise in working with other organizations. The sales department can help, although it usually lacks the detailed and specific technical knowledge needed in working out uses for new products. Certainly the principal work on utilization should be done by the development department.

Economic Studies

At the time of the research activities, and certainly before the development expense is incurred, a preliminary evaluation should be made to determine the general economic feasibility of the proposed process. If the product is a well-known one like phthalic anhydride, obviously any new process should use starting materials which cost less than the final product. When the new product is entirely different from old ones and has greatly improved properties, however, an economic study may not be very revealing. No one could say beforehand what the traffic would bear relative to a new anti-freeze. Ethylene glycol was obviously going to be more expensive than methanol by a considerable margin, but its lower volatility made it worth considering as a replacement for the cheaper product.

The preliminary economic study also indicates how extensive the pilot plant work should be. For a new product of known utility with a wide margin of profit, or for a substantially cheaper way of making an established product, the pilot plant work can be comparatively limited. If the new process is a way of turning crude oil into soap, at a cost of two cents a pound, the pilot plant need demonstrate only that the process actually works. If the process is one which the economic study shows to be barely competitive with existing processes, however, extensive pilot plant work will be necessary in order to establish yields and costs and find out whether or not the process will actually show a profit. In such cases the potential market must be a large one. Otherwise, it is a bad gamble to sink money in expensive pilot plant work which may result simply in an adverse decision regarding the process. In the case of a common product, the preliminary economic survey should also include a number of items which under other circumstances might be considered part of the market research—transportation costs, packaging costs, and so on.

The economic work should not stop when the pilot plant work has begun but should go hand in hand with it, to determine what yields, recoveries, and the like are economic. Where a product is made to rigid specifications which have already been established, as in the case of making toluene for nitration to TNT, the economic studies seek merely the cheapest way of making a product of those specifications. Frequently, however, characteristics of the final product are less definitely settled. In considering manufacture of the new product, there arrives a point beyond which chemical engineers could certainly go to make a product of greater purity, but there is a question whether this greater purity is worth the cost of obtaining it. When performance of equipment can be predicted from fundamental data, as is now largely true of distillation columns in the petroleum industry, and when the value of the products obtained is well known in terms of easily measurable characteristics such as octane number, the economic study can be carried out on a calculating machine, without pilot plant results. Usually, however, there are uncertainties about desired purity and the cost of obtaining it.

These must be resolved by combined pilot plant, economic, and utilization studies.

If possible, the preliminary economic study should include some consideration of pricing policies. It may be desirable to manufacture a small amount of material for a market which can stand a high price, or larger quantities with a smaller profit per pound. It is a particularly desirable situation if two potential markets exist—one a high-priced market which will guarantee a return from the research and development expense, the other a larger but lower-priced field which can be included after the initial production problems have been solved. Research executives of the B. F. Goodrich Company have said that development of the Company's polyvinyl chloride resins was possible only because housewives were willing to pay a high price for shower curtains and other products made of Koroseal. The eventual larger uses developed after the high-priced household uses had been taken care of. Cellophane also went through a preliminary high-priced period, followed by a great increase in usage as the price was dropped. Nylon had the advantage of a market which would stand a high price per pound even in substantial quantities.

Complexity of Economic Studies

The economic studies should include a wide variety of factors. Many of the questions have rather obvious answers, but they should not be forgotten on that account. Some of them relate to the supply of raw materials. Is the supply limited? Is it subject to wide price fluctuations? Is it seasonal, requiring a large investment for inventory? Is it obtained from a foreign source? Is it vulnerable to tariff changes? Is it controlled by a single supplier?

If the answers to these and similar questions are unfavorable, the margin of profit in the new process must be adequate to compensate for the risks, or else the company must take steps to reduce the economic dangers. Flour mills eliminate their raw material problems (in a free market) by hedging their purchases. E. I. duPont de Nemours & Company eliminated the one-supplier hazard in its tetraethyl lead operation by absorbing the Roessler & Hasslacher Chemical Company, supplier of the necessary sodium. Although steps can frequently be taken to remedy the economic disadvantages of raw materials, the most desirable new process is, of course, one which uses common and widely available substances such as coal, air, petroleum, limestone, and sea water.

In addition to the consideration of raw materials, the preliminary survey should consider economic problems connected with the process itself. While detailed questions regarding the final product should be left for a market research study, there should also be a preliminary glance at market characteristics of the product. Is it a necessity or a luxury? Is it subject to wide price fluctuation? Will it mean competition from other commodities? Is labor a high proportion of the costs? Can the equipment be used for other purposes if the intended present use proves unprofitable? These and a number of other questions can be answered fairly early.

Factors concerning the character of the competition should also be considered. If the competitive products already have a high margin of profit, or are by-products and must therefore be produced in any case, it may pay the competitors to engage in a price war to drive the new product out of the field. Even the ethics of the probable competitors should be considered in forming the final economic judgment regarding a new process. As chemical economist D. P. Morgan[7] once pointed out in discussing the influence of business risks, "The typical chemical industry, manufacturing producers' goods which are sold by a relatively few men to comparatively few buyers, whose prices are not published, is particularly susceptible to . . . price concessions, although there are, of course, other tricks in every trade."

In addition to contemplating present competition, the development department ought to maintain an active lookout for possible future competitive processes which may render the new development obsolete. Building a plant for propane oxidation may be undesirable if there are, looming on the horizon, Synthol plants which will produce a number of the same alcohols and aldehydes in quantities large enough to affect the price of these products.

Although in general, economies are realized by increasing the size of equipment—since stills, evaporators, filters, etc., require about the same amount of labor and supervision in small sizes as in large—there are instances in which small plants have an advantage. The agricultural chemical industry, for example, must supply fertilizers for soils which differ from county to county. Small mixing units widely distributed throughout the country are in the best position to manufacture fertilizers tailored to fit the needs of each locality.

After all the economic surveys have been made, it should be recognized that an occasional process is desirable even if it will not itself make money. If it will complete a line of products, and thus assist the sales force, it may pay off in the form of indirect economic benefits.

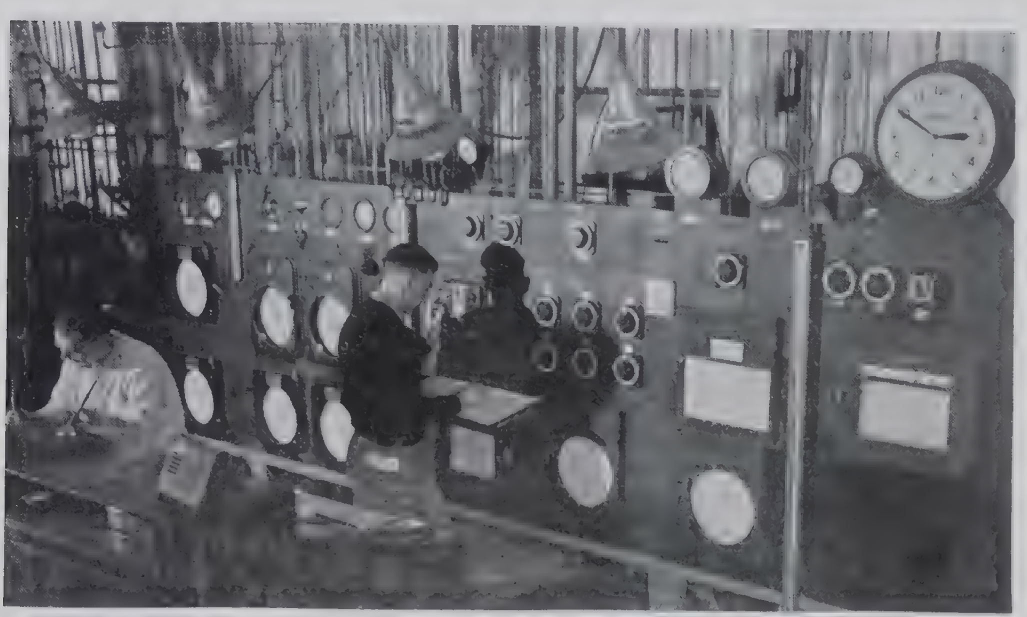

PHOTO. 8. Main control board of a Synthol pilot plant. *(Courtesy of Standard Oil Company of Indiana.)*

Process Design

Process design of a new or improved operation or a modification of an old operation is an important development function which involves translating to commercial scale data obtained by pilot plant investigations and economic studies. In view of this dependence upon other groups for background material, there must be a close relation between the process design, pilot plant, and economics groups. In the petroleum industry process design is concerned with operating conditions, process flow, equipment size, product specifications, etc. It usually is not concerned with matters of mechanical design, such as equipment specifications, layout of facilities, design of foundations, supports, pumps, lines, and furnaces, or with integration with other plant facilities such as steam, utilities, sewers, and so forth.

In the process industries, where such factors as operating conditions have a considerable or even a controlling effect on the nature of the product, process design must be a part of the development department. In the mechanical and electrical manufacturing industries, however, factors like flow of materials have little effect on the finished device, though they may have a large effect on the efficiency of the operation and consequently on the profits. In such cases, where the quality of the product is largely independent of the methods by which it is put into large-scale production, the principal work of the development department is done when the new device has been reduced to a final approved prototype which embodies no particular manufacturing pitfalls. In these industries "production engineering," which corresponds to process design work in the process industry field, is properly a function of the manufacturing department. A production engineering revision group, however, may be part of the development department, with the task of making in the design any alterations which are needed to introduce economies, per-

PHOTO. 9. Engineering design is an important part of development. (*Courtesy of the United Shoe Machinery Corporation.*)

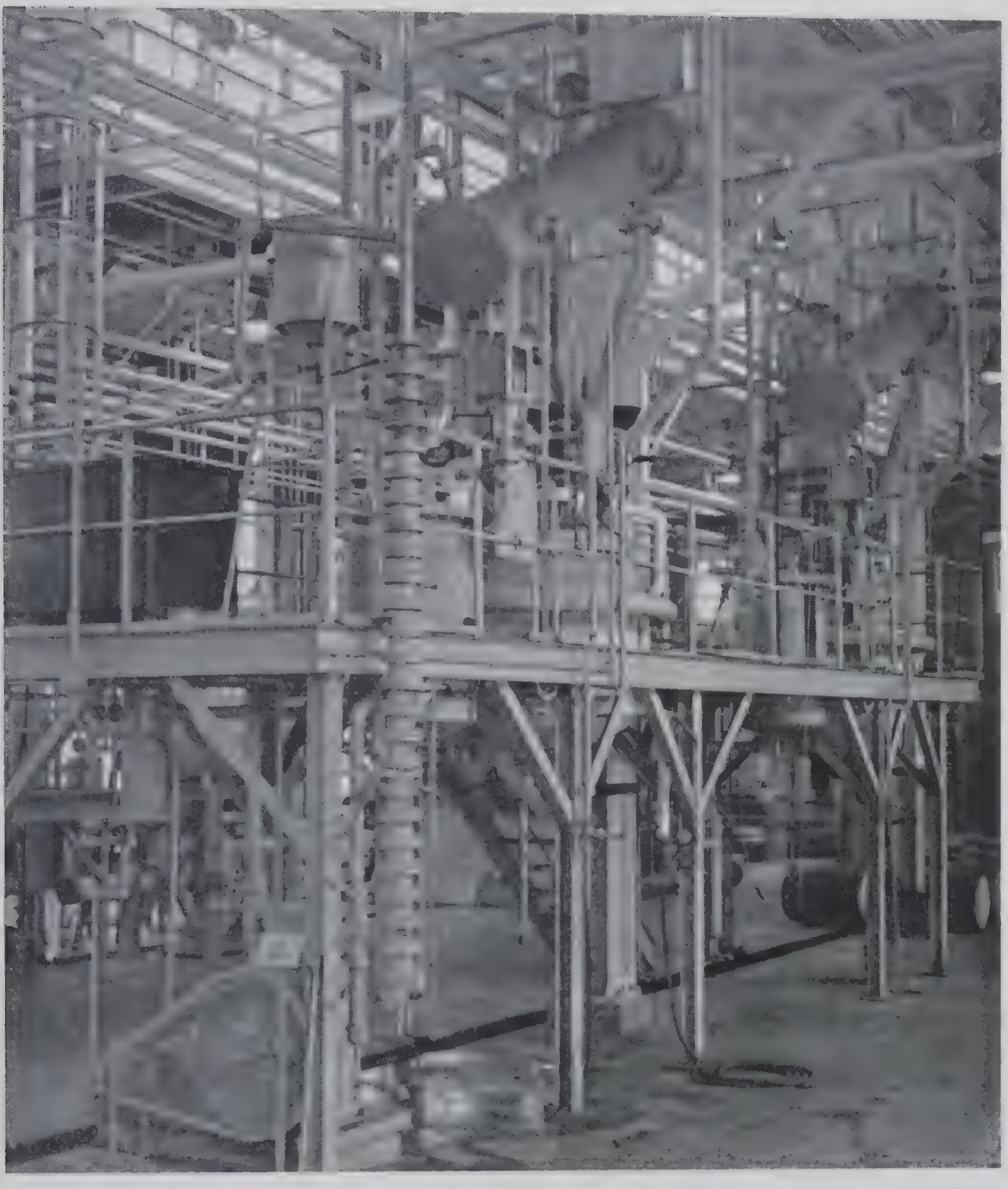

PHOTO. 10. Distillation equipment in a chemical engineering pilot plant. (*Courtesy of The American Cyanamid Company.*)

mit production on existing equipment, correct any weak points which develop, etc.

Different companies handle the organization question in different ways. The important thing is that all the significant findings of the pilot scale work be translated fully to a larger scale by the method which is most efficient for the given situation. Process-design people in the petroleum field must be conversant with chemical engineering design techniques regarding fluid flow, heat transfer, material transfer, distillation, absorption, filtration, and other unit operations, and must have at their disposal necessary information to permit reliable process designs to be made. As a consequence, considerable time must be spent in compiling and correlating fundamental chemical engineering data as well as in devising new and improved process-design methods.

While process-design operations are primarily those described above, process-design engineers are required to fill several other no less important functions. They consult with pilot plant groups and advise them in planning experimental programs. They co-operate with economic groups by providing data for both exploratory and firm economic appraisals of new processes and new products. They supervise process-design work done by outside contractors. It is also their function to revise current operations and to consult with the manufacturing department in planning new operations to fit product requirements which have been changed as a result either of expansion of existing operations or of a change in market conditions. Of necessity, process-design engineers must work closely with mechanical engineers to assist in selecting proper equipment for translating the process-design flow sheets into an operating unit. This close co-operation with mechanical engineers is particularly important in establishing equipment-performance guarantees for the contractor to meet. The process-design group of an oil company must keep up to date on all types of refining operations for possible use in the company's plants. They must also assist technical service groups in planning and carrying out tests on units already in operation, in order to provide reliable information upon which future process designs can be based.

Parallel Developments

While the responsibility of the development and design groups of a chemical company, particularly if it is a large one, does not include the details of mechanical or electrical equipment, it is recognized that these are parallel fields which are also of great importance. In many instances the mechanical engineering department of the company, or an outside engineering firm if one is employed, has sufficient definite knowledge at hand to complete the details of mechanical design as soon as the process design is completed. On the other hand, extensive new developments involving primary or auxiliary mechanical or electrical equipment are sometimes necessary before the new process can be implemented. A great deal of the work of the Manhattan Project involved the development of entirely new pumps, conduits, diffusion barriers, and automatic controls which were a prime necessity before the processing of material for the atomic bomb could become a reality. In such instances one of the major managerial problems revolves around the adequate co-ordination of the work done by the various groups or industries which are carrying out the parallel phases of the over-all development.

The final development of many chemical processes may be delayed or even ultimately abandoned because of the lack of an adequate material, pump, or control device. After the invention of oil cracking, further evolution of the new process was handicapped by the difficulty of pumping hot oil. Invention of the surge pump solved this problem and permitted further advances in the art of cracking. Later, still better pumps were perfected. A process involving the handling of very corrosive materials at high temperature and high pressure may have to be placed on the shelf until some metallurgical genius devises an alloy to meet the new and stringent requirements. Some of the new processes involving use of anhydrous hydrofluoric acid at high temperature are now in this situation, particularly with regard to gasketing material.

Within recent years a number of industrial chemical processes have been utilized which involve the use of high vacuum. These new developments were delayed until relatively large-scale, high-vacuum equipment (essentially a mechanical engineering development) became available. It is a question whether the need of the chemical engineers for such equipment induced mechanical engineers to develop it, or whether the mechanical developments came first and the chemical applications followed. In the case of the high temperatures and pressures required for thermal cracking of oil, the sudden large demand for new construction methods and materials called into existence highly productive research in the metallurgical and fabrication fields. Whatever the relation between cause and effect in each case, the advances are usually made in small increments in the parallel fields. It is quite likely that the advance would be much more rapid with a planned and over-all integration of the efforts in the two lines of activities.

It will always be a question how much initiative the chemical process group should take in promoting new developments of desirable or necessary mechanical or electrical equipment, or new fabrication materials. There is no magic formula which can be applied. If the unfilled need represents such a major step that no one can foresee the means of accomplishment, then it would appear that the project should be postponed or abandoned until someone else does the necessary research. If, however, a new parallel development in the mechanical field has a reasonable probability of success, the chemical process engineer might well be justified in carrying out his own activity, while assisting the necessary mechanical development

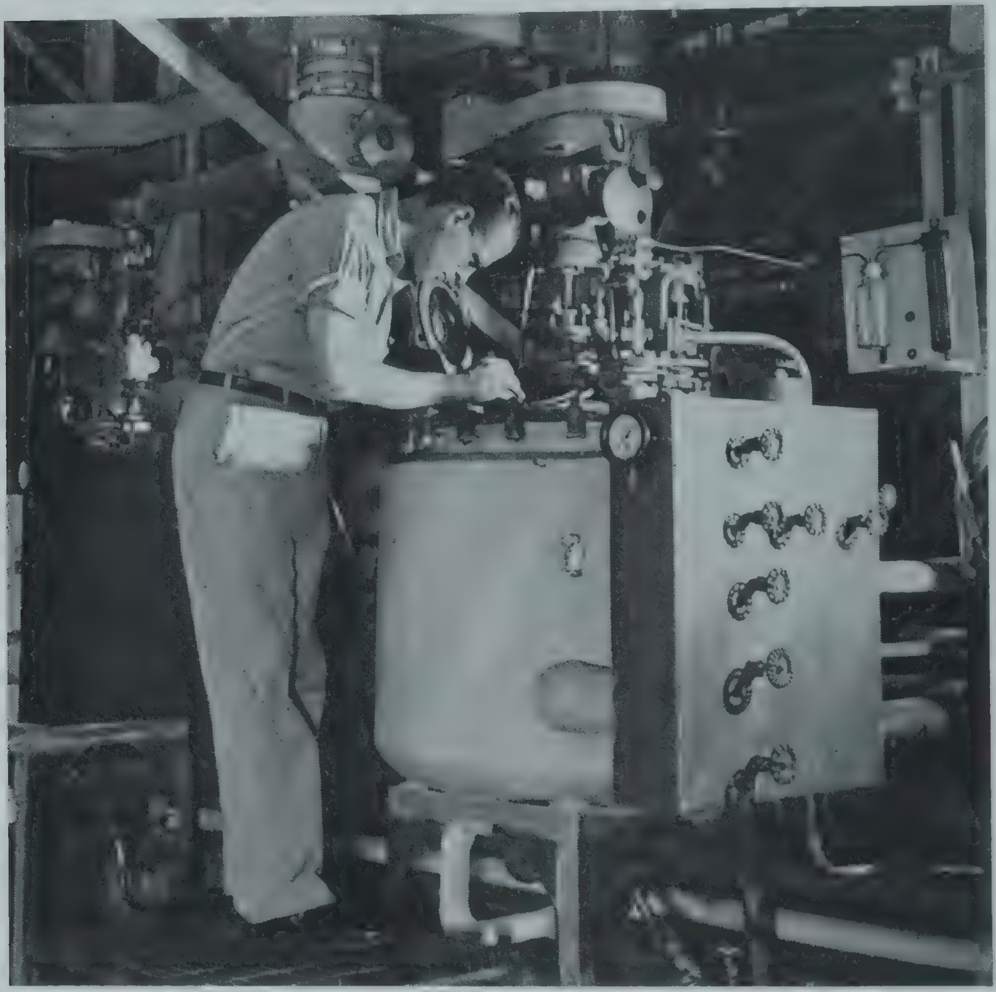

PHOTO. 11. Chemical pilot plant operation. (*Courtesy of the Monsanto Chemical Company.*)

through whatever organizational channels are necessary. If the success or failure of his particular process hinges on the success of the parallel development, complete collaboration of the two groups is probably assured.

The scientific and engineering developments which were stimulated by World War II have resulted in many new devices and processes that have a great deal of industrial utility as yet by no means fully realized. The striking advances in intelligence and actuating systems arising from radar, fire control, and bombing systems have many possible applications in industrial process controls. There will also be applications in industry for many of the developments which had to be made in connection with atomic energy: highly inert plastics, improved mechanical pump seals, leak detectors of high sensitivity, high transfer-rate heat exchangers for gases, and improved centrifugal gas compressors, to name just a few.

PHOTO. 12. A laboratory model shop. Development activities often require working models. *(Courtesy of Radio Corporation of America.)*

If mechanical and electrical developments have important implications for the process industries, the reverse is also true. This is especially so in the field of new materials, which often have important impacts on mechanical or electrical design and on customer acceptance. To synthesize an example, we might consider the development of a new vacuum sweeper. In this case mechanical design is the critical part of the program and would be handled by the development department. It is necessary to work out a design which is satisfactory from the mechanical point of view. It is also necessary to consider housewives' preferences, and many other factors. The new design might call for a considerably more powerful motor than had been used previously. With the conventionally designed motor the whole device would become too bulky and heavy to be acceptable. But a significant change in motor design made possible by use of the new glass-fiber insulation might radically reduce the size of the motor and bring the whole project back into the realm of feasibility.

From the foregoing discussion, it is obvious that those responsible for development work—the translation of the research idea into a practical process or device for production—must be prepared to cover, or at least be cognizant of, many lines of activity, not only in their own special field but in parallel ones. Though any one industry has its specialty in which it is well versed, it cannot live unto itself alone. The development problems of all industries are not only interrelated, they are intertwined to a surprising degree.

Market Research

The ultimate aim of commercial development work is to create a product that can be sold at a profit. In order to avoid putting effort and funds into a product that is not salable in a volume or at a price necessary for adequate return, detailed market research should accompany technical development. Such research is simply an organized search for all facts that might affect the market for the product, combined with a critical appraisal of the facts discovered. Let us assume that the product under consideration is called "neodol." Market research attempts to answer the question, "If we were to make neodol, how much of it could we sell and what price could we get for it?" Depending on the nature of neodol, the questions involved in the market research and the technique employed in that research will vary widely.

If neodol is altogether unique, like nylon, a product never before produced by anyone, market research must obviously resort to different methods of appraisal than will be used in the case where neodol is a product long manufactured by a number of firms and widely distributed. Again, the techniques employed, where neodol is a highly specialized product used by a limited number of industrial firms, will be different from the techniques employed if neodol is a generally used household item bought daily in thousands of retail stores.

Market research seeks by one means or another to determine demand-supply relationship. More accurately, it seeks to determine the future demand-supply relationship and to anticipate the situation that will exist when neodol is ready for full-scale production. In solving this problem, questions similar to the following usually have to be answered.

Those on the demand side are typically:

1. Who uses, or might use, neodol? Is it used by manufacturing plants, or by farmers, or by housewives, or other groups? Further, exactly what kind of manufacturing plants, what group of farmers, what class of housewives?
2. What use do (or could) these specific groups make of neodol? How do they use it? Is its use essential or casual in the different consuming groups?
3. What is the total actual and potential consumption of neodol by all users?
4. Where are the actual and potential users located geographically—by regions, states, cities?
5. What specifications or qualities are required or preferred by different consuming groups?
6. What are the buying habits or preferences of each consuming group? Do they buy infrequently or often? In large or small lots? What sizes and types of packages do they prefer? What service do they expect or require in connection with purchases of neodol?

On the supply side, questions that must be answered, at least in part, before a sound appraisal can be made include the following:

1. Who are present manufacturers of neodol? Many or few? What are the resources of each in funds, plant equipment, and technical skill? What is the history of each, generally as a business organization, and, specifically as a producer and distributor of neodol? Considering each producer individually, is neodol a product of prime importance or is it of secondary or even less importance in the over-all operation of the company? Is the company affiliated with others? What are its close business associations?
2. How is neodol marketed—direct from manufacturer to consumer or through distributors, wholesalers, jobbers, etc.? Is it marketed in different ways to different consuming groups—e.g., to industrial users direct and to institutional users such as schools and hospitals through

jobbers? What credit terms and discounts apply, and do they differ to classes of consumers?

3. What are the sales policies and practices of competing firms? Do they rely largely on personal solicitation? On mail? On intensive general advertising? What promotional and publicity programs do they employ? Are their customers loyal or indifferent or even resentful?

4. What is the history of neodol? What has been the trend of production—total and by individual producers? Has the number of producers increased or declined? What has been the price trend—steady or fluctuating—up or down? What products compete with neodol? What is their history and what are their future prospects?

Sources of Information

The above compilation by no means exhausts the list of questions that should be answered if a sound evaluation of markets is to be made. The questions selected are intended only to illustrate the kind of problems encountered by market research. Obviously there will be a wide difference in the ease and also in the accuracy, with which they can be answered. Finding the answer to a particular question, moreover, will present little difficulty in the case of one product, but will be almost impossible in the case of another. For all cases, however, the sources of information to be consulted will be found in two broad classes—literature and personal contacts. In most cases it will be advisable to make use of both categories. Even though published information may be extensive on a particular product, it is nearly always wise to obtain first-hand information from the field, to check or supplement information obtained from the literature. On the other hand, a background literature search is usually necessary as a basis for appraising material secured through personal contacts.

Literature sources (with some overlapping) are:

1. Technical literature—textbooks, technical society publications, reports of technical associations, etc.

2. Market literature—trade papers and periodicals, trade association releases, advertising of producing companies, trade directories, etc.

3. Government publications—these cover a tremendous quantity and variety of statistical, marketing, and economic data in almost every field. The federal government, especially, issues great quantities of information essential to market research. In come cases, the states and small subdivisions of government also issue information of value.

4. Semi-public organizations—chambers of commerce, social agencies, and similar semi-public or subsidized non-profit organizations publish information of interest in certain fields.

In passing it should be said that quite often present manufacturers of the product may be approached directly and frankly for information.

There are, in general use, two means of obtaining direct information from users or potential users of a product under consideration:

1. By personal interview with users or potential users. The interview may be highly formalized—a fixed set of questions, with the answers checked by the interviewer on a prepared form. At the other extreme, it can be altogether informal, consisting of a free and casual discussion.
2. By mail inquiry to persons from whom information is sought. This also can take the form of a carefully prepared questionnaire wherein several answers are provided and the respondent simply checks his choice; or it may be a letter requesting an individual response on the part of the recipient.

There is nothing spectacular about the technique employed by market research. Successful results require, primarily, a meticulous attention to detail in collecting facts and a painstaking appraisal of their significance and relative importance. Considerable ingenuity, however, is often required in this collecting and relating. In some fields, notably those dealing with consumer markets, surprisingly skillful psychological and statistical procedures have been developed for increasing the scope of market research and the accuracy of its results. Since market research as a formalized or organized activity is receiving more and more attention in connection with development programs, it is reasonable to assume that its effectiveness will increase and that it will be used more generally than it has been in the past.

Market Research Staff

Although it is desirable to have a specific group solely responsible for market research and for no other function, the size of this group varies widely from firm to firm. In some cases it consists of only one or two people. In others, the central staff may include a dozen or more specialists (statisticians, analysts, etc.) under a director and several assistant directors, and there may be, in addition, a field interviewing staff of perhaps a hundred, with the necessary supervisors. Obviously, the type of organization and its size will depend upon the nature of the firm's business and the market research job to be done. Some firms employ only a small permanent staff, relying on the personnel and equipment of independent market research agencies, of

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which there are a number, for any necessary help on specific jobs or extensive surveys.

Just as there are wide differences in size of market research departments, so are there wide differences in the cost of market research. Generally speaking, market research is not cheap. The type of personnel required is of a caliber to command substantial remuneration, and it has been found to be woefully false economy to attempt market research with an inadequate or inferior staff. Moreover, in addition to relatively high salaries, there is also often sizable expense for travel.

Because of the considerable expense, and the frequently intangible benefits, there is the feeling on the part of some excutives that market research is unprofitable. In this connection, the following excerpt from a publication of the American Management Association [1] is pertinent:

> Some research studies take only a few hours or days to complete, while others may require as much as several years of intensive and sustained effort. Business executives, in general, have learned that research studies in such fields as chemistry and engineering may extend over long periods, but it is often characteristic of these same executives to underestimate seriously the amount of spadework that must be done in investigating the various angles of a major sales or marketing problem. They fail to grasp the fact that it is necessary to develop and test certain hypotheses even though the data may be very difficult to obtain and the end results may prove inconclusive or negative. The resulting executive impatience with the research staff, through lack of understanding and appreciation of the work and the problems involved in the conduct of a scientific study, tends at times to discourage dependable research and to stifle the urge of research personnel to explore vital, if more tenuous, avenues of development.
>
> Patience and expanding managerial vision may be counted upon to overcome the retarding effects of the time factor, as well as of some of the other influences. Improved techniques and evolving standards in the field will exert a similarly beneficial effect. Fortunately, the executives who express greatest enthusiasm for the role of marketing research management are becoming more alert to the nature of the factors limiting its highest effectiveness—a condition which augurs well for continued progress in the direction of encouraging sounder practices, more wholesome attitudes, more able workers and greater accuracy in the interpretation of findings and their application to actual marketing operations.

In addition to the publication from which this quotation is made, others dealing in detail with market research are mentioned in the references at the end of the chapter.[2, 3, 8]

A series of articles entitled "Sources of Chemical Market Data"[6] to be published in book form in the fall of 1947, contain a wealth of information on the best places to find data of interest to many concerns others than those engaged solely in chemical marketing.

Producers of certain products are fortunate in that they do not need to carry on market research work. A process which is known to produce a high-octane (anti-knock) gasoline at low cost does not need any further guarantee of its acceptance. This means simply that in certain fields the market is accurately known, the price which the consumer will pay is also accurately known, and the product evaluation methods are so all-embracing that they permit complete testing in the producer's laboratory. For all these things to be true, the product must be one which is produced by a number of competitive firms and is sold in such quantities that a great deal of work has been put on evaluation methods. It is interesting to note that before evaluation methods were available—in this case before the knock-test engine was invented—a superior product sold actually at a lower price than the inferior product then in use. Because of a minor objection regarding odor, the first cracked gasolines had to be sold for less than straight-run gasolines. It was not learned until years later, by means of the knock-test engine, that cracked gasolines gave better performance than the straight-run product.

Most development projects are in a less fortunate position than one which produces a high-octane gasoline; they require market research and related economic work.

Co-operation with Other Departments

The interest of the development department in the new process does not stop when it has been turned over to the plant construction department or to the contractor who is to build the new equipment. The members of the process design group continue to act as consultants to the engineering department. When the equipment has been completed, the development department follows the start-up and the carrying out of the performance tests.

When the unit is functioning satisfactorily, the development department provides information on the product for use by salesmen. Usually technical articles describing the new development are prepared and presented by technical men at scientific meetings. They are followed by semi-technical articles for other publications, but these semi-technical articles should also be written, or at least closely supervised, by technical men.

Market Development

There is probably no part of development which is handled in more widely different ways than market development. In some companies it is part of the research and development department, and in the authors' opinion that is where it should be. Some companies, however, have been able to operate quite satisfactory market development departments as a division of the sales department. This question was ably discussed by Charles Gabriel[5] in a symposium conducted by the Division of Industrial and Engineering Chemistry of the A.C.S. Mr. Gabriel comments as follows:

> There are undoubtedly differences of opinion as to whether the market development should be a division of the development or sales departments. Because its staff contacts customers, or prospective customers, many sales managers believe it should be under them to avoid possible friction with the salesmen or their customers. On the other hand, the contacts of the market development man are with the customers' research department, even though these may be made initially through the purchasing agent. He has nothing to sell except possibly technical information which, to serve the customer, must be used first in his research department. Since he has nothing to sell, he cannot be judged by the same standards as is the salesman whose efforts result in sales volume. The market development man is interested chiefly in finding markets for new products being developed. He does not quote prices, although he should be able to give the prospective user some information in regard to the approximate price range in which the product will eventually sell in order that the latter may determine, from an economic standpoint, where it may be used by him. The representative of market development is naturally desirous of furnishing samples to those who have evinced sufficient interest in the product to undertake some research work on it. The development department must be in a position to supply such samples promptly, as a delay may have an adverse effect on the interest of the prospective user. Proper follow-up of the sample by well-timed visits is important. The market development man is really engaged in chemical research involving an exchange of technical information between his development department and those of prospective customers. The information which he obtains is helpful more in guiding research than sales activities. He must attend technical meetings such as those of the American Chemical Society to have the opportunity of continuing discussions with his contacts away from business surroundings. For these various reasons, his place is in the research and development department. When a newly developed product has reached the production stage, its marketing, of course, should be in the hands of the sales department, with market development furnishing such help as may be requested.

Unless the product has a more trouble-free history than most new projects, the development department will need to follow it closely for a long time, to help iron out the difficulties that arise. Technical service to sales will, of course, continue as long as the company continues to sell the product. The continued assistance of technical men helps the product to find a firm market and then to branch out into new uses. If all the steps in the development process have been sound, it can be expected that the new product will make money and will finance the development of still other new products.

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CHAPTER IV

The Research Director's Job

Responsibility

The research director's job is the most important one of all the technical positions in a company, and, without danger of overemphasis, one of the most important in the entire executive family, when the long-term success of a company is considered. This may appear so obvious as to be a truism. Yet it needs to be reiterated, for it is not uncommon to find in this important post, even in quite large companies, men whose main qualification for the position is executive ability, with neither the scientific training nor the experience in research which is demanded.

The director of research or, as the writer[7] prefers to designate him, the chief or manager of research—since these terms imply less of the idea of dictation, regulation, or command—must be a leader and inspirer of men. The really successful one does not dominate the whole research program. He creates, in his laboratory, the atmosphere and environment conducive to obtaining the co-operation and best effort of his men, but he does not set himself up as a dictator. When it comes to the actual direction of the details of research, he is, as Kenneth Mees,[4] so often quoted on this point, says, usually the least competent, next to a research committee, to guide the course of an investigation. Even the importance of the group leader is questioned by Mees, who gives the top importance to the man at the laboratory bench, who really knows the details of his problem and how best to solve it.

Top place, however, must be granted to the research director, for without his stimulating leadership and guidance, the motivation, enthusiasm, and will-to-research are not instilled in the research

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This chapter by N. A. Shepard, Chemical Director, American Cyanamid Co.

organization. One has only to consider the history and success of some of the largest, oldest, and most productive industrial laboratories to realize this. The names of Willis R. Whitney, Frank B. Jewett, Charles L. Reese, and Charles F. Kettering are synonymous with the research laboratories of General Electric Company, Bell Telephone Laboratories, E. I. duPont deNemours & Company, and General Motors Corporation respectively. These laboratories are the shadows of the men who founded them, and who inspired their staffs to create and invent.

It was Edward D. Jones[6] who defined the executive's job as that of providing in a group of men "harmony of mood, harmony of attitude, or the desire of all to accomplish the same thing." This admirably expresses the fundamental job and broad major function of a research executive. If he can do this, the efficiency and productivity of his research group is assured. As Schell[6] states, the "success or failure [of executives] . . . will not be measured primarily in terms of their technical knowledge nor in terms of their technical skill, but rather in terms of their effectiveness in handling men and women." Obviously, in the case of a research executive, technical knowledge and skill, together with broad and personal experience in conducting research, are prerequisite to successful research management. Lacking the ability to handle men, however, a most productive scientist himself will not be able efficiently to lead a research group. In many organizations the director of research is not the most prominent scientist in the group, nor does he hold the highest scientific honors, or have the greatest number of patents and discoveries to his credit. But he is, or should be, a true leader of men.

Authority

In an industrial organization the position of the manager of research, with respect to the various other department heads, nontechnical executives and top management, is of great importance to the effective functioning of the research department. Complete definition of authority is essential if the manager of research is to do his best work. In many companies the director of research is a vice-president and is thus in the best position to guide the technical progress and affairs of his company. As vice-president in charge of research and development, he can exert the greatest influence on the broad policies of his corporation, and this recognition of his importance has a marked effect on the morale of the research organization itself. His men have greater respect for him, and it leaves no uncertainty in the minds of the staff as to the place and importance of research in the eyes of top management. This is not an insignificant point. It has much to do with the individual scientist's contentment and efficiency. If, coupled with making the research director an official of the company, especially if he is also on the board of directors, top management adopts a policy of unswerving support of research, year in and year out, regardless of economic conditions (in so far as the financial strength of the company will permit), then the research worker knows that that company is a good one with which to cast his lot—one where he will have an opportunity to follow through and bring his problems to a fruitful conclusion, or logical stopping point.

It should be said, of course, that when a research organization has become large, it is quite impossible for a vice-president research director to carry all the duties incumbent on a top executive and at the same time manage research. He must relinquish the actual direction of research and appoint either an assistant to handle these duties or create a separate post of director of research, reporting to him. This will not change the situation as regards the actual chief of research having a direct channel to top management.

Industrial Research vs. University or Institutional Research

The problem of managing an industrial research laboratory is, in many respects, quite different from that of directing university or institutional research. In the case of the latter, practical application of the results is ordinarily not necessary. The problems are and can be chosen with complete disregard of the dollar sign—can be selected purely for their scientific interest or value, and may be of so deeply fundamental a nature that their solution is problematical or doubtful. Such research gives the worker complete freedom of thought and his individuality can have full sway. The problem is not assigned to him; he selects it himself.

In the industrial research laboratory it is quite a different matter —a "horse of another color." The work is not supported by private endowments, fellowships, or government funds, but by the profits from the use of stockholders' money, and over the years, it must pay out. This places limitations on what shall be researched. Some men, and even the research director, may chafe under this restriction.

but it is a necessary one. If such a restriction detrimentally affects their happiness and contentment—with the accompanying enthusiasm so essential to success in research—then those men and that director should return to a university or institutional laboratory, where there is complete academic freedom.

A wise research director realizes this limitation of industrial research and will give his men as much freedom as possible in selecting their own methods and procedures in attacking their assigned problems, and even in choosing their problems. When a new problem comes up for assignment, he will not bluntly allot it to investigator "A," but will discuss the problem with him and find out how interested he is in it. If the director fails to arouse any enthusiasm for that problem, he will, or should, cast about for some other man in the organization who is also qualified to handle the particular investigation and who finds the problem intriguing and chooses to tackle it. It is deadening to have an unsavory problem unnecessarily forced down one's throat, and even a less competent chemist, physicist, or engineer, who has interest in and enthusiasm for the project, is likely to solve the problem in a shorter time, and thus conserve manpower. Of course, especially in these postwar days, with the pressure for immediate solution of this or that problem which is "on the books," and with each investigator crowded with all the work, and more, that he can do, new-problem assignment is often determined by who it is who can take on another task, rather than by who wants the problem or who is truly interested in solving it. It is for this reason, that a good policy is to permit each worker to spend a certain percentage of his time on unassigned work—perhaps even up to 20 per cent—in which time he can follow out his own hunches and ideas along any line he desires. Obviously, the sensible man will confine himself to problems which have probable solutions that will benefit his company. Many important discoveries have been made, and new lines of research opened up, during such "fishing" excursions.

Again, the research director who has finesse will not over-direct. Detailed supervision of each man's work, with insistence that the research director's ideas on mode of attack must always be right and be followed, leads to dissatisfaction on the part of the research worker and definitely impairs the output and efficiency of a research and development laboratory. No one man has a "corner" on ideas, and the adage that "two heads are better than one" has vital meaning in research. Mees[4] shows perspicacity when he envisions it as the research director's job to "protect the worker from those who would direct."

There is a compensating factor in this limitation of the type of problem which is justifiable in an *industrial* research laboratory, i.e., compensating to the investigator. This is the stimulation of knowing that if the problem is solved the findings will have practical application and will influence either the quality of one of the company's products, or will lead to a new product, or will effect savings and, in any case, influence the balance sheet. This thought is stimulating to most men and is a compensation that the university scientist only rarely realizes, especially if he insists, as indeed he should, that his major problems be of a more fundamental nature than those the ordinary industrial laboratory is justified in attacking. We would not seem to imply that such fundamental work is of lesser importance —the reverse is quite the case—but the stimulation of seeing one's work put to good use promptly is one of the things that goads the industrial scientist to his maximum effort.

Formulating the Program

In the writer's opinion, the research director should have full, absolute, and final authority over the research program. If he does not, the program will be in an almost constant state of flux, disrupted by the whims and snap judgments of pressure groups, not only in the sales department and other commercial departments, but in the research laboratory itself. Obviously, the director must be influenced by and must listen to every department of the company. He must keep his ear to the ground to detect, in advance if possible, the various needs of these departments. Excellent suggestions come from all over the company, from the president on down, from the plant operators, and especially from the sales department and its field representatives who are in direct and regular contact with the customer. While these field men are more likely to be keen eyes for the evaluation and development laboratories than for the research department itself, many things are brought in by them which show the need for fundamental research. As the writer[8] has said, the sole responsibility of the research director for the approval of problems, as well as for the elimination of unwise ones and the termination of unfruitful investigations, is too great for any one man, however wise, to carry without benefit of a great deal of sound advice and preliminary investigation. This is the reason why, in the writer's opinion, the director should have the benefit of a technical advisory and co-ordinating committee. It is important that such a committee should be purely advisory in nature, with absolutely no authority over the program. A research committee with power to dominate the research program is, as Mees [4] has said, a menace and probably the worst possible method of attempting to manage research. But an *advisory* committee is quite another matter, if properly organized and manned by capable, experienced men. Among its members should be the research director, a seasoned operating man, and a member of the engineering department. The sales manager, if he be technically trained, can add much to the deliberations of the committee, but it is usually unwise to include a division manager of sales in the group, as he will be too likely to be influenced in his decisions and recommendations by departmental considerations. If there is a technical man of long experience with the company's activities, one who has broad outside contacts, as is often the case with the chemical director, he should be an asset in the advisory committee. An experienced lawyer or technically trained patent attorney may well be included in the roster. In selecting the personnel of the committee, thought should be given to naming men who come from the various divisions or subsidiaries, if it be a large company, so that the danger of provincial recommendations will be avoided. This committee, if functioning properly, uses, of course, every source of information in the company—the sales department in all its branches, patent department, market research, and engineering department. It should report not only to the research executive, but its findings and recommendations should be available to the management and budget committees.

As indicated above, the task of formulating and regulating the research program taxes the most astute of research managers. Certain principles, which can well be enumerated and emphasized, should regulate his decisions.

The first responsibility of the research department is to guard the quality of the existing products of its firm and to protect the volume of business on these products. It is not enough to maintain existing quality and uniformity, through the efforts of the plant control department, which has the responsibility of maintaining the quality of the raw materials, uniformity of manufacturing conditions, and quality of the finished product. Research on improved methods of manufacture that will lower costs and/or raise the quality is essential if the company's position on the product is to be maintained and improved. A market always becomes more and more competitive the longer the product has been on it. This backlog of the business—the existing products—must be the first concern of the research director, and must never be relegated to second place, regardless of how enticing and lucrative new-product research may appear.

Another principle to which most successful companies adhere quite rigidly is that of placing great emphasis, in formulating the research program, on those projects which relate closely to the existing business and products of the company. Adopting such a policy means that a certain amount of manufacturing know-how is already existent and that the existing sales force will be in a position to handle the new products.

A third principle, which applies particularly to a chemical company, is that of searching for new products based on, or using as intermediates, materials already manufactured by the company or requiring raw materials on which the company has a preferred position. It is all too easy to be enticed away from these fundamental principles into lines of investigation far afield from the company's business and preferred position on raw materials and, in so doing, fail to discover the "Acres of Diamonds" [3] lying close at hand, almost within grasp, and developable at a fraction of the research expense that would be required in distant fields.

Careful consideration must be given to the proportion of the budget that is to be allotted to fundamental research. The urgency of demand for present-product improvement, as well as the size of the budget, should have a strong influence on the decision. Except in a small research organization, with a very modest budget, some fundamental research should be a "must," if proper provision is to be made for continued company progress in the years to come. The research director must keep his eyes, not only on next year and the following year, but on goals five or ten years ahead. Basic research will insure the future of his company, provided sound business management is maintained. It is probably trite to add that, once embarked upon, fundamental research must be prosecuted vigorously and continuously. Men who are capable of conducting basic research will not tolerate frequent interruption of their research program to conduct hurry-up development work, or "fire-department" stop-gap trouble shooting.

The Research Budget

As the question of formulating the budget is discussed in another section of this book, it will not be covered here in any detail. It should be emphasized that this, in the last analysis, should be one of the research director's duties. As a result of long experience with the "ins and outs" of research and the successes and failures, he will be able to predict with some degree of accuracy what an investigation is likely to cost. The determination of the amount of the total budget is regulated by the breadth of the company's research policy, the percentage of the profits which it deems wise to plow back into research, and the over-all picture of the necessary year's expenditures as presented by the director of the budget and or the budget committee.

It is the research director's responsibility and duty to see to it that the budget requested for a given project is likely to prove adequate for the work involved, and not give the management a false idea of the cost of solving the problem. The "big bad news" should be told honestly at the start. Management does not like to have its research director habitually come back for more funds.

Again, it is the research director's task to sell his management the necessity of arriving at an over-all budget that can be maintained, regardless of the ordinary fluctuations in profits. It is at least as unwise to adopt too large a budget as it is too small a one. There is an intermediate amount which is safe, involving a budget that experience has shown can be maintained. Once that is established, it should not be reduced so long as the financial strength of the company will permit that expenditure. Continuity of personnel is vital to research success. A budget which fluctuates to any marked extent, now up and now down, and necessitates even occasional reduction in staff, followed later by re-expansion, soon convinces those research men who were retained that the company has no firm, fixed policy on research, and that that laboratory is not stable enough for them to risk their positions and careers in it. Green-light, red-light, stop-and-go research appeals to no man, whether the reason be a fluctuating budget or a vacillating policy on the part of management or the research director.

Intermittent support of research, if persisted in, will put a company "in bad odor" with technical men, and eventually that company will find itself under a handicap in obtaining the services of scientists. The universities soon become cognizant of the situation and the professors openly advise their students, when they are seeking employment after graduation, to avoid such companies.

Maladjustment of Professional Employees

Another responsibility which the director and all other management has, and to which altogether too little attention is given, has been forcefully pointed out.[5] This is the director's duty to watch his men closely for symptoms of breakdown, physical or mental, caused by unhappy personal relationships in the plant or laboratory; by trying to fit square pegs into round holes; by bringing in outsiders to fill key positions instead of promoting employees of long service; by countenancing irritating policies and red tape; by an "all-business" attitude of disinterest or disregard for his men and their personal problems; by refraining from any words of encouragement or praise; by emphasizing shortcomings and defects, while ignoring strong points; by being always critical instead of complimentary and, what is far worse, criticizing his men in front of others; by driving his men beyond reason and failing to note indications of overwork; by failing to develop and maintain his sense of humor; and by adopting a generally "bossy" attitude.

All these things may lead, on the part of the employee, to worry, to mental degradation if not breakdown, to physical illness, and may eventuate in death. To avoid such conditions, the research director, his assistant director, and his junior executives must be close enough to their men that these maladjustments will be quickly detected; they must be understanding enough to take immediate steps to rectify such situations where possible. Failure to do so may mean the loss of key men, if not through illness, through resignation. Many times the sensitive and temperamental men in an organization are unusually important ones, especially brilliant, conscientious, and hardworking.

There is a less serious but equally important side to this matter of a friendly and understanding attitude on the part of the laboratory management toward the research personnel, which the research director fixes by his own example. Unnecessary turnover of personnel is less final than death, but equally effective in causing the loss of men's services. It is a common complaint among industrial technologists that their superiors show a lack of understanding and of interest in them; that they are so busy that personal contacts are all too rare; that they are unwilling to discuss the shortcomings of their men and to explain why advancements in position or in salary were not forthcoming. All employees want to grow, and they particularly appreciate constructive criticism from the boss, especially from the director himself. The director's door should not be only ajar to his men; it should be wide open.

Remuneration of Staff

We shall not dwell here on the responsibility of the research director to see that his staff is properly and fairly remunerated. To do this job well requires a great deal of thought and attention. It is not enough just to meet the starting salaries for new graduates—salaries which are more or less fixed by supply and demand, and at any given time may become standardized. It is the remuneration after several years of service, when a man's abilities (and limitations) have become recognized, that the question of his salary needs careful consideration. After a few years, it is not enough to bring him along on a standard percentage increase per year. Differences in ability, as compared with the others who came into the organization at the same time as he, will be showing up. On the basis of these varying abilities, salaries should show considerable variation and spread, regardless of the position that the man may currently occupy. Failure of the director to keep posted on these developing talents, either directly or through his section heads, or his indifference to such talents to the extent that nothing "out of the ordinary" is done to recognize them, will unquestionably lead to the loss of a brilliant supporting staff. Competitors may be more keen in observing these budding qualifications and lure some of the best men away. Indifference to this matter, or a niggardly policy on increases, soon detected by professional employees, can easily wreck plans for the future organization.

This whole question has been exhaustively covered by Adams,[1] who especially emphasizes the tendency to overrate new men and to overlook those who have served for many years. The research director may well neglect some of his directing of research problems and take time off to study the salary sheets in the light of the competence and accomplishment of an individual and his importance to the organization.

Selling Research

Over a period of years, research, if properly organized, manned, and supported, will sell itself. "By their works, ye shall know them" aptly applies. But during the adolescent stage of a laboratory—and this may mean a period of five or six years, or even longer, before a major development brings profits—the research director has the task of keeping research sold to the management. There is little possibility of keeping the laboratory "out of the red" during that period, and it is practically hopeless to make any attempt to evaluate the incomplete investigations in terms of future profits. It is during that period that the management must live on faith and realize the long-range nature of research. It is important that management comprehend that fact fully before it embarks on a research program.

Later there will be a time when the results begin to come in and to pyramid. Then it will become possible and desirable for the research director to present his management with something tangible regarding the financial status of the laboratory and its influence on the profit sheet of the company. Some managements start out with the idea that it would be nice to have a research laboratory, that it is something a company really ought to have—a competitor who has one is becoming tougher and tougher competition, and perhaps his laboratory is responsible for this. "Anyhow, let's establish a laboratory! We'll charge it to overhead and insurance and perhaps something will come out of it that will be important to our company." This attitude may persist for quite a few years, but eventually there comes a day of reckoning when the president gets suspicious that the laboratory is costing too much money for the return the company is getting. Then he calls in the research director for an accounting and the latter tells in glowing terms of the interesting results he and his staff are getting, and how promising these findings are for future sales and profits. He points out that certain improvements in quality of products have resulted, but can give no tangible profit figures, except certain reduction in raw materials costs, or perhaps manufacturing costs. It is all quite unconvincing to the hard-boiled business executive.

So there comes a time when some scheme of evaluating the output of the laboratory is a "must." Both the research director and top management want to know, and need to know, the facts. Of all the methods devised, the following appears to this writer to be the best.[9] The accounting department—preferably the general accounting department, not the laboratory accounting department, if there is one—prepares and presents to the president and the other executives a list of the products which the company has, which it would not have had, except for the laboratory. Itemized on this list are the volume of sales, the sales value, and the factory profit for that month on each item. Included is the cumulative figure in the profit column.

It is a relatively simple matter to make these calculations on new products; it is not quite so easy to evaluate the research department's influence on old products. Increased sales over the normal sales curve, following a quality or design improvement for which the research department was responsible, shows, however, where the accruing profit should be credited.

It may appear that such a procedure gives too much credit to the laboratory, and in a sense that is true. All that the laboratory did was to discover, evaluate, and develop the product, probably through the pilot plant stage. Then the engineers took hold of it and designed and erected a plant. This was then efficiently operated by the plant manager and a quality product turned out. Still there were no profits until the sales department, with the able assistance of the advertising department, explored and/or created the demand for the product and consummated the sales. Hence this was a teamwork proposition and no one department can claim, or should claim, entire credit for the profit that has accrued. This is all true, but the fact remains that, if the product is a new one, *that profit would never have been realized if the research laboratory had not existed and that product been developed there.* So, crediting the laboratory with such profits is entirely justified. It will cause no trouble in the organization, through the jealousy of other departments which played major parts in making the thing a success, provided it is clearly defined that the management has no hallucinations that the laboratory is solely responsible for this profit, and provided that credit, where due, is given to other departments.

Of course, such a picture presented to the management does not tell the whole story as regards the value of the laboratory to the company. Improvements in quality of old products, unless they have been brought from losers to profit winners, do not appear on the list, but savings in materials or manufacturing costs of such standard items should be added as they show up in increased percentage of profits or, if the saving was passed on to the consumer, may appear in increased sales.

There are many intangible services given by a research laboratory and its staff—advice of various kinds to the sales, advertising, legal, and other branches of the organization. These cannot be evaluated, but it is not necessary to do so. The tangible items covered above will usually be, after the adolescent period, so outstanding as they accumulate, that the management no longer will need to be sold on the importance of its research department to the company's business and profits. Bolton's [2] figures on duPont's experience are illustrative: 46 per cent of the company's gross sales in 1942 came from products which either did not exist in 1928 or were not then manufactured in large commercial quantities.

Building Bridges between the Scientific, Operating, and Commercial Departments

Finally and last, but not least, the research director has a co-ordination job of almost overwhelming proportions. If it is a large laboratory, he has the task of welding the various groups and divisions of the laboratory into a smooth-running whole. If he does not give attention to this matter, he may find himself attempting to lead a group of municipalities, each primarily interested in its selfish aggrandizement, both in size and accomplishment. Sparring for departmental reputation, regardless of its effect on the output of the laboratory as a whole, is a favorite pastime of some department heads, and this attitude will soon influence and infect each individual in the department. A real director of research will take drastic steps to prevent such a scission.

Equally important to the research department's productiveness is the establishment of friendly co-operative relations with *all* other departments of the company, and especially with the sales, production, and engineering departments. Williams[11] has given a particularly lucid exposition of this necessity. The sales department needs to have the closest relations with the research department, especially with the evaluation and development divisions, and the need is just as great from the laboratory's standpoint. The research director should preach co-operation at every opportunity and at once step personally into any breach that threatens to destroy confidence in the laboratory's motives or co-operativeness. And the same holds true with regard to relations with the plant or plants. The results of research are stymied, and translation into profits retarded, unless the research department works in close harmony with the plant operators and engineers. Calls for help from these departments should receive immediate attention. And in the case of the plants, where a difficulty arises which is beyond the capacities of the plant control laboratory and is sufficiently important to tie up research personnel and equipment, such difficulty should be promptly investigated. Failure to do this means trouble ahead, when the research department needs plant development work on its products.

It is difficult to define exactly how these bridges are built, strengthened, and maintained. They are built gradually by continuing co-operation, strengthened through personal contacts, and maintained by vigilance. It is well for the laboratory to foster "visiting firemen" and, in turn, to encourage research workers to visit the plants and sales offices, and exchange thoughts and ideas with the men in the various commercial departments.

Recapitulation

It seems clear, then, that the research director has a job requiring unusual talents, ranging from executive-ability and all that that implies, to technical training, skill, and experience, and to an unusual understanding of human relations and psychology. He must possess imagination, intuition, enthusiasm, and leadership of the highest order. Unfortunately, there are all too few men with such qualifications, and most companies have to be satisfied if their research executive measures up to these demands in a fair percentage of respects. With upwards of three thousand research laboratories already established in this country and many more projected, the market for highly qualified managers of research is not likely to be glutted.

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CHAPTER V

Organization Charts in Theory and Practice

General

Organized research eliminates haphazard experimentation. It substitutes system for chance. It becomes an aid to industry, a help to a research worker, and a benefit to society.

The main functions of research in any form are:

To cure troubles as they arise.
To anticipate and prevent trouble.
To improve the quality of materials or products.
To develop new processes, materials, or products.
To develop new uses for existing products.
To effect savings.
To abate nuisances.
To develop new products to meet an existing market or to create new markets.
To assist in standardization.
To develop better customer and public relations.

The place of an industrial research division in the company's structure should always be very close to top management. This is necessary in small as well as large organizations.

It should be represented directly to and supported by the president or a vice president of the company or a committee consisting of the heads of the sales, production, financial, and engineering groups. The general organization of a research department resembles that of any business, having a director, assistants, supervisors, and a staff of men whose capabilities are commensurate with the work at hand.

When starting a research department, the program must be planned over a long enough period to produce results. It requires

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This chapter by W. E. Zieber, Director of Research, York Corp.

time to produce results because the individuals, represented by the names on any chart, are human beings and must be considered as such and handled intelligently with the understanding that they are not production people, turning out a product in a specified time.

To be completely logical, a research organization should correspond to a functional chart of research activities, with each step carefully defined. But the definitions of research are as nebulous and varied as the definitions of poetry. Moreover, organizations are built of men, in a framework of pragmatism and history, and hence seldom follow any completely standardized pattern, however carefully conceived such a pattern may be.

In order to present the principles of sound organization, however, it is necessary to build the argument around some framework which is consistent within itself. One analysis of the steps of scientific, inventive, and technical steps involved in the stream of activity from first conception was presented as a flow chart in Chapter I. This can be used as a framework for the discussion of organization charts.

In keeping with that outline, the division of activities of a complete industrial research laboratory might be considered as follows:

1. Fundamental Research—The qualitative and quantitative investigation of the phenomena and laws of nature.
2. Exploratory Research—The "try and see" approach to the investigation of processes, materials, or devices, with or without a preconceived objective. This is the particular realm of the inventor.
3. Applied Research—The application of the findings of fundamental research and the results of exploratory research to the reaching of a preconceived objective—a successful working process or device.
4. Development—The application of technology to the improvement, testing, and evaluation of the process or device resulting from applied research.
    - *a.* Engineering and production of service test quantities as for electrical or mechanical devices.
    - *b.* Design, construction, and operation of pilot plants as in the process industries.
    - *c.* Service testing of devices or processes.
    - *d.* Application research or technical services, with prospective customers on new devices or processes.
    - *e.* Market research and evaluation.
5. Production Research.
    - *a.* Investigation of new production methods.
    - *b.* Investigation of methods of standardization and control.
    - *c.* Specialized "trouble-shooting."

Though a complete industrial research organization might be responsible for all the activities listed above, they are not all, in the strict sense, research. There is no universal agreement on what does constitute research, but the majority of those who wish to define it would concede that the first three categories—fundamental, exploratory, applied—do come within its boundaries. Development and production problems are usually considered to be in an area outside of research itself, but merging into research activities.

It must be emphasized that an industrial research laboratory does not have to enter into all of the activities outlined above to be effective. Only in the largest organizations can there be economic justification for setting up a formal organization that would give major emphasis to all the phases. Fortunately, research activities in many industries can be effectively built up in relatively small increments—more or less cafeteria style—if careful planning and foresight are continuously employed. Some successful laboratories have had their genesis from small beginnings in the activities of item *5c*—specialized "trouble-shooting." Others have initially focused all efforts on applied research and have then branched out toward both development and fundamental research. Company policies on the extent of research activities are rightly affected by the size, the product that is sold, the future business or type of product desired for sale. The successful company carries on as many of these research functions as are necessary.

The Ideal Organization Chart

In the consideration of an organization which might be ideal for carrying on the various research functions, it is necessary to keep in mind that the best research men are not only technical specialists in particular fields, but that they are most effective in a function and environment which maintains their interest at a uniformly high level.

The personnel trained and naturally adapted to do fundamental research seldom desire to carry on other types of research although there are some who have the diversified technical ability to follow a product from fundamental research through production. Personnel trained and naturally adapted to do development, production, control laboratory, or application research seldom, if ever, are able, or have the inclination, to carry on fundamental research. Because of this, fundamental research is usually operated on a subject basis rather than a product basis. The other types of research are more often performed on a product basis.

The above clearly indicates that shifting of personnel in the fundamental group must be mainly on problems relating to the science training or experience of the men. The other types of research allow men to be shifted to the different types of research as well as to different products, as long as the work is in their field of training, but seldom, if ever, can they be used in fundamental research.

Market research is not sufficiently stabilized to designate the type of personnel required. It is carried on by a group of specialists who consult with companies and make surveys. Scientifically trained research personnel have not shown aptitude for this type of work. This type of research is generally a sales department function. Also, some sales promotion departments have supervision of this research.

Since the objective of industrial laboratories is ultimately to focus activity on the development of specific devices or processes, their organizations are usually of the convergent type. Departments or teams may each deal with physical chemistry, organic chemistry, chemical engineering, electronics, mechanics, X-rays, etc. Eventually, they will converge on the theory and practice of the company's product. All men have their own special field of work, their activity overlapping in other departments, their general knowledge extending over a much wider range so that they are not only interested in other investigations but can be mutually helpful.

When setting up a research organization it is practical to delegate authority and describe the various functions and relationships and illustrate them on an organization chart. The ideal organization chart is primarily to fix responsibilities, duties, and relationships, but it is difficult—in fact, almost impossible—to adhere strictly to an organization chart in research.

The control of duties and responsibilities in a fixed relationship in an industrial research organization, as would be required by an ideal organization chart, is not possible in all industries. The nearest approach to such control of an ideal nature is possible only in the largest industrial organizations. This is because they manufacture large quantities of products, parts of which must be worked upon constantly to improve materials or design. This allows them to have fixed personnel working upon these items year after year. A large part of their research work would be of this type, thus eliminating the shifting of personnel from one item to another as is necessary in smaller organizations. This means the largest companies will have the more fixed organizations and more closely approach the ideal organization chart in their research functioning. Such organizations as General Electric Company, Westinghouse Electric Corporation, Bell Telephone Laboratories, Standard Oil Development Company, and Aluminum Company of America are examples of this type.

Generally, the larger companies carry on all the research functions of fundamental research, including the appropriate academic contacts, as well as development, factory research, factory control, application research, and market research.

Two Types of Organizations

Research organizations are of two different types. In one the strictly research activities are carried on by a completely separate organization, responsible to top management. In this type of organization, development, factory research, control laboratories, and application research are carried on at each product's division headquarters. These latter may be located at widely different points.

The second type of organization is one in which all types of research are carried on in one location under one top executive. Each department in this type of organization, such as fundamental research, development, factory research, control laboratories, and application research, has a man in charge who is particularly trained and adapted to his type of research. The department heads are responsible to one common top executive.

With this type of organization all laboratory services are under one head who serves all departments. It is more economical to operate in this manner, but it can be accomplished only when all types of research can be located at one place.

The Isolated Research Organization

A suggested organization chart in the case where research is carried on as a more or less isolated activity is shown in Figure 2. The program of this department includes exploratory, fundamental, and applied research. Development and production research activities are carried on under the engineering department of the product division whose vice-president is responsible for the profit and loss picture of that product. Our illustration shows two product divisions, but some companies have as many as fifteen such divisions. The research group, in such a case, is generally arranged according to sciences rather than products, although they can be under both of these headings.

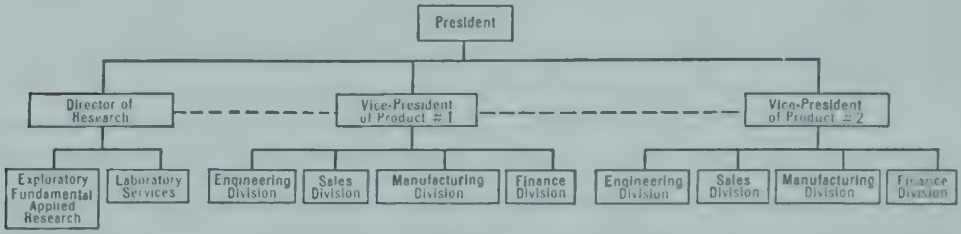
President
Director of Research
Vice-President of Product # 1
Vice-President of Product # 2
Exploratory Fundamental Applied Research
Laboratory Services
Engineering Division
Sales Division
Manufacturing Division
Finance Division
Engineering Division
Sales Division
Manufacturing Division
Finance Division

FIG. 2. Separate research department.

In such a research department the personnel are generally used as consultants to the development departments in the various manufacturing organizations. It is possible, however, that at times these men are allowed to follow through the problem until it is completely in production to be sure that the details are thoroughly understood and that the product is satisfactory.

The research group would have supervision of all research carried on in universities and colleges for the company. This may be research carried on under scholarships and fellowships through grants from the company sponsoring it or may be research fully paid by the company. Companies support such research because of special equipment located in the university or because certain personnel there are acquainted with this type of problem. They also support fellowships to train and observe prospective employees. Research organizations which carry on this type of co-operative work with universities are functioning at General Electric Company and Westinghouse Electric Corporation.

Research Laboratory Services

Laboratory services are similar in all laboratories but all functions may not be set up individually in small laboratories. In large laboratories there is enough work to allow one or more persons on each function.

Laboratory services are usually under a supervisor, sometimes called an administrator. He may be technically trained, according to requirements. He handles all services to allow the research personnel to function without bothering with the business or special construction phases of the laboratory.

When a manufacturer has a separate research laboratory as in Figure 2, with development work at each division headquarters, the laboratory services in the research laboratory would be similar to those shown in Figure 3.

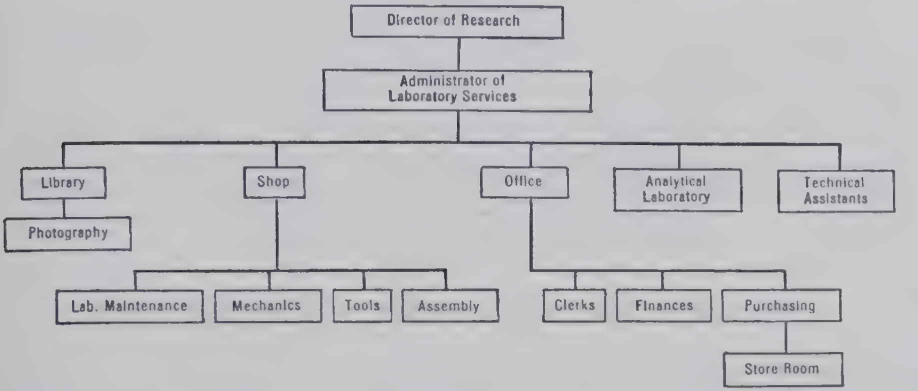
Director of Research
Administrator of Laboratory Services
Library
Photography
Shop
Office
Analytical Laboratory
Technical Assistants
Lab. Maintenance
Mechanics
Tools
Assembly
Clerks
Finances
Purchasing
Store Room

FIG. 3. Laboratory services for separate research.

In certain types of business or manufacture of products the research laboratory would have under its jurisdiction a group of special instruments such as spectrograph, X-ray diffraction apparatus, and special chemical analysis apparatus to serve special problems of the entire laboratory.

The design, building, and operation of apparatus for research, in some cases, require the services of engineers who operate under the administrator, if he is technically trained, or under a technically trained assistant to the administrator.

Development and Factory-Research Activities

The engineering divisions under vice-president in charge of products No. 1 and No. 2 as shown in Figure 2 may have a development and production research organization under a director of research.

An organization chart for such a research organization is shown in Figure 4.

The organizations in the separated product divisions of a large company, as illustrated in Figure 4, may have laboratory services nearly as elaborate as those in the separate research laboratory. This means that laboratory-services personnel must be set up in each of these divisions. This is more expensive than under those conditions which permit all research to be located at one place. The science library is not so necessary in the division research as in the fundamental and applied research department. The division research library

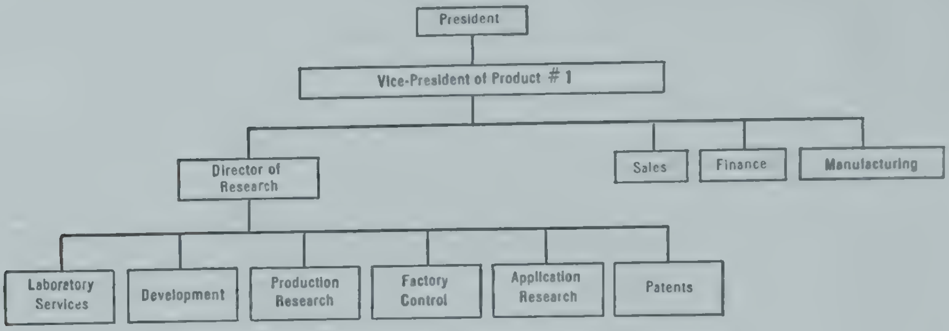
President
Vice-President of Product # 1
Director of Research
Sales
Finance
Manufacturing
Laboratory Services
Development
Production Research
Factory Control
Application Research
Patents

FIG. 4. Development and production research.

consists mainly of literature pertaining to products, methods, and general engineering. Figure 5 illustrates a suggested laboratory-services chart for the development and production research organization.

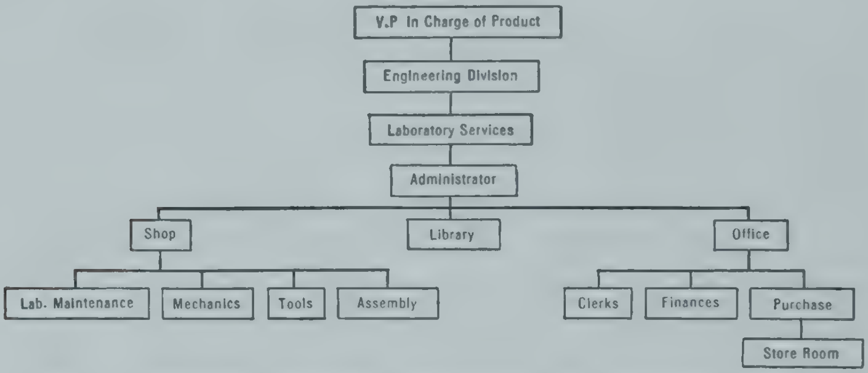
V.P In Charge of Product
Engineering Division
Laboratory Services
Administrator
Shop
Library
Office
Lab. Maintenance
Mechanics
Tools
Assembly
Clerks
Finances
Purchase
Store Room

FIG. 5. Laboratory services for development and production research.

Complete Research Functions at One Location

An organization chart in the case where all research is located at one place and supervised by one top executive is shown in Figure 6. The director of research as the top executive is in charge of all research, development, laboratory services, patents, factory research, factory control laboratories, and application research, with the appropriate assistants and proper supervisors.

When factory control is under this executive, the business is of such a nature that research and development departments are able to prescribe factory control methods and instruments from their work. Such industries as non-ferrous metals or alloys, and oils are representative of those following this type of organization. Factory control can be centrally located, even though manufacturing plants are scattered, by having research write the prescription and their man follow up the factory control laboratories.

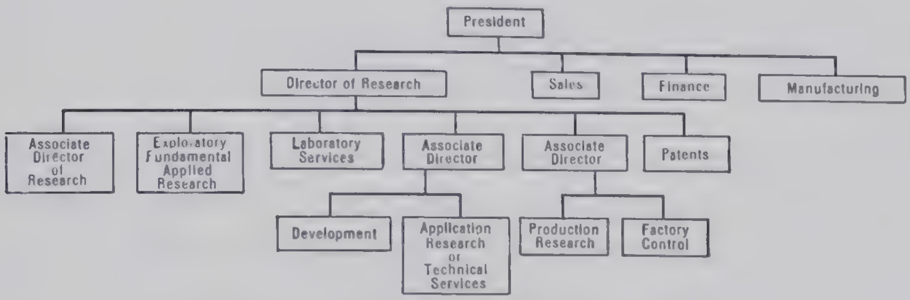
President
Director of Research
Sales
Finance
Manufacturing
Associate Director of Research
Exploratory Fundamental Applied Research
Laboratory Services
Associate Director
Associate Director
Patents
Development
Application Research or Technical Services
Production Research
Factory Control

FIG. 6. Combined research and development.

Production research, in industries which have large production of one item, comes under the director of research because research and development create the articles to be manufactured, make all designs and piece drawings, and are responsible for factory inspection.

The research department receives the assignment or approval of its projects directly from management. These should be of a long-term nature. The head of this research group must keep his personnel flexible enough to serve short-term projects that might come from other departments even though the long-term projects are sometimes delayed. The personnel are generally set up according to their science training. The research (fundamental, exploratory, and applied) is usually under an associate or assistant director of research.

The development work is usually assigned to an associate or assistant director of research. He supervises engineers to develop or improve products from information obtained by fundamental research or from other sources. These engineers have close contact with such draftsmen, shop men, and test engineers as are necessary to complete their work. The development engineers are constantly making changes in engineering standards as their work progresses. They acquire personnel to revise and add to all engineering standards.

The services of industrial designers or stylists are constantly used in many development groups. Such services are frequently obtained on a consultant basis.

Factory control laboratory methods and requirements usually originate in applied research and development work. The supervision of these control laboratories is responsible to a top executive so that all new things can be handled promptly. All problems brought out by the factory control group, from the manufacturing standpoint, can be quickly and satisfactorily adjusted as to design, and vice versa.

Production research which deals with improvement of production methods and materials, requires a close tie-in with applied research and development, and the supervisor of both activities will be responsible to one top executive. Research in some industries works very closely with the development department. In some industries this work would go past the pilot plant or trial lot stage into design of factory equipment to produce the products. Some of the engineers in this pilot plant stage would follow the designs to the factory to help design and build the tools or apparatus for production.

Application research, or technical service, in some industries, is so closely related to research and development that its supervisor is responsible to the same top executive.

Production research and factory control laboratories are generally arranged so that their supervisors are responsible to an assistant or associate director of research.

The supervisors of development and application research are generally responsible to an assistant or associate director of research.

The patent personnel can do a better job if they are under the jurisdiction of the same top executive as research and development. They must advise constantly regarding the patentability of an idea, as well as on the infringement phases of patents.

Some large laboratories operating with this type of organization are Bell Telephone Laboratories, Standard Oil Development Company, and Aluminum Company of America.

Laboratory Services for the Combined Research Departments

Laboratory services for the combined research departments are similar to those set up for fundamental research in Figure 3.

It is necessary to have personnel in the purchasing, filing, and stores departments who understand the problems of each of the types of laboratories. In the large laboratories these functions may be set up for each type of research. There is economy of operation of laboratory services when research functions can all be located at one place.

The analytical laboratory and the technical assistants are both dependent upon the type of business for which research is being carried on.

Variations from Ideal Organization Chart: Medium-Size Organizations

It is very difficult to retain fixed ideas of organization in research work. The larger organizations can justify an approach to the ideal. The following illustrations show some modifications that must be considered in medium-size organizations.

The medium-size organizations are considered to be those companies which employ from 16 to 150 professional personnel in research and development activities. Even though the functions of research may be the same in a manufacturing organization of any size, the size and type of a business often determine where the research is to be done and the type of supervision desired. To be permanently successful a medium-sized company should plan to carry on applied research, development, factory control laboratories, market research, application research, and to maintain control laboratories. The type and size of the business has much to do with grouping of the various functions.

A company may make one product in large quantity, such as 150,000 electric household refrigerators per year. It needs applied research, development, factory research, factory control, and application research. Each of these functions would be carried on by a group with a supervisor responsible to a director of research. Models would change only once every two or three years. The development and factory research phases must be finished before trial models are built. Thus, when the application research is finished, the specifications are set for a few years. The factory control and inspection groups could then carry on. If they only manufacture, and the selling is done by another organization, the selling organization would carry on the application research. When the seller demanded new models the director of research would obtain necessary personnel for such work.

This manufacturing concern may choose to carry on its fundamental, exploratory, and applied research at a university or an industrial research foundation instead of its own laboratory. The follow-up would be made by the director of research. Figure 7 shows an organization chart covering such an industry. Some chemical companies would operate with such an organization.

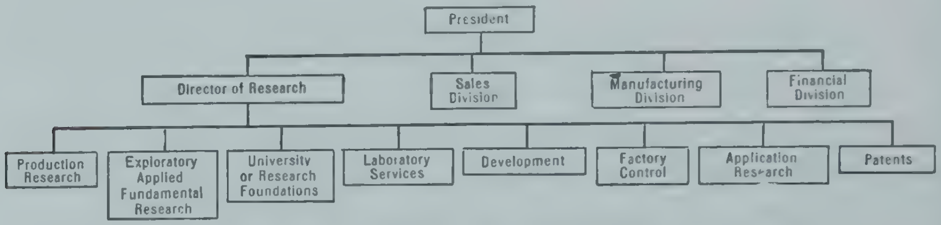
President
Director of Research
Sales Division
Manufacturing Division
Financial Division
Production Research
Exploratory Applied Fundamental Research
University or Research Foundations
Laboratory Services
Development
Factory Control
Application Research
Patents

FIG. 7. Medium-size research and development organization.

The pilot plant phase in the chemical plant is the same as the trial lot in the refrigerator company's research organization.

The application research is carried on by a group of field contact men who bring their problems to research and are responsible to the top executive in charge of research.

The other functions are the same as those outlined for the refrigerator business except that all functions might be carried on constantly.

Some industries requiring considerable development and engineering, in this medium-size group, would need all the functions and the setup shown on organization chart Figure 4.

Regardless of the number of organization charts which might be made, and the type of system that might be desired by the head of any company, there is no group in research which can be held strictly to organizational lines. Red tape must be avoided as much as possible. It is impossible to standardize and regulate things too closely in research laboratories. If this is attempted, the best creative work cannot be brought forth. For instance, it may be necessary to take a man out of a certain field and place him in charge of a project because of his past experience or natural inclinations. The training and inclinations of the man in charge of a project have much to do with its success.

A research organization must be flexible enough to adapt itself to any change of structure in the company and its business. The smaller the organization, the more flexible it should be. To keep a research organization on its toes requires constant vigilance and adoption of methods and procedures, in accordance with the knowledge gained by the personnel and changes in the company's business due to that knowledge.

Personalities have much to do with organizational setup. One man may be capable of handling more than one project even, in large laboratories, as many as five to seven projects. Another man may be a lone wolf, but very good at his individual work. Both types can be successfully employed in research when their inclinations and abilities have been properly evaluated. Sometimes research and development departments are built up during the growth of an organization, so that functions and duties overlap considerably as the growth progresses, and make it hard to draw lines between the functional duties of certain people. Moreover, many an organization is constantly in flux because of research discoveries which change the types of business.

No organization chart can accommodate the changing requirements of the particular organization involved, or the personnel that must be placed, or the ideas of the particular supervising group about how the functions should be broken down.

A project may develop to the phase where several angles can be worked on at one time to obtain information to complete it. The supervisor or director will shift personnel into such a project and slow down less fruitful ones to get that particular project into management's hand promptly.

Any illustrations that might be given can neither cover all types of organization resulting from widely differing executive personalities nor meet all the requirements of various industries. By using parts of several charts, however, the requirements of any business might be fulfilled.

Small Organizations

In small organizations—that is, those employing 15 or fewer professional personnel—the over-all functions of research may be the same as the large organizations even though the activities are more restricted. Some of the personnel may be required to carry on more than one duty. Figure 8 shows a typical small-company research organization chart. The patent work would be handled by the company's legal group.

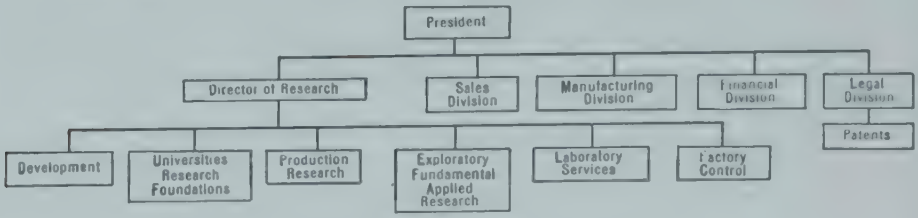
President
Director of Research
Sales Division
Manufacturing Division
Financial Division
Legal Division
Patents
Development
Universities Research Foundations
Production Research
Exploratory Fundamental Applied Research
Laboratory Services
Factory Control

FIG. 8. Small research organization.

Most small companies concentrate on development. The development group and the production research group are so closely tied together in their functions in many organizations that they are placed under an assistant director of research. This facilitates smooth functioning of the close relationship necessary between these two groups. Some development personnel might be assigned to application research on the product on which they are working.

In some businesses it may be more desirable to have application research, or technical service, carried on by personnel who act as engineering advisers to salesmen in contact with customers.

It may be desirable to have fundamental, exploratory, and applied research performed at some university. It is recommended, however, if at all possible, that one or two scientifically trained men be retained in the company's research group to carry on exploratory and applied work. It is best to have them in one's own organization, rather than lose the benefits of the personal contact and control.

If an outside laboratory is considered because of its specific abilities—either personnel or facilities, or both—the control will come under the research executive. He will appoint a man who is acquainted with fundamental and applied research to contact and guide its operations.

The small company can obtain many of the technical facts needed to carry on its business by having the research personnel keep in touch with technical institutions and professional-society activities. Such groups gain much knowledge by working in close contact with suppliers and with customers.

Two Systems of Handling Research Programs

The internal organization of the various research departments generally functions according to one of two systems, known as the *project system* and the *team system.*

The *project system* is that in which one technical man heads up a problem, designates the method of attack, and assigns the steps of the work on the problem to the individuals who assist him. He controls the end result and gets credit for it. This project system works best in places where a single field of science or some single product of simple nature is involved, with someone capable of handling people to work out the details that are to be handled by assistants. The problem may be in the chemical, chemical engineering, or straight mechanical field, and not include other fields of science. Certain types of problems on ceramics, metals, or obtaining aluminum from clays, would illustrate the problems to which this system can be applied.

The project system is the one generally used by a small organization, although a large organization may apply it to a specific problem. Men of creative minds and initiative, however, will normally resent working for a man in charge of such a research problem because they will have to do only the things delegated to them by the project leader and will receive no direct recognition for their work. In such a system there must be the strictest kind of organization because the head controls each man's operation—that is, the method of attack, the instruments and apparatus necessary, and the determination of when to stop or change a method of procedure. All technical planning is done by the leader.

The *team system* is used where two or more fields of science are involved. A problem might involve lubrication, chemicals, corrosion, heat flow, machine design, sound, vibration, heat, and metallurgy. Such a case would involve physical chemists, chemical engineers, mechanical engineers, metallurgists, and physicists. The problems might be of such weight that each field of science could be headed by a man thoroughly capable of taking charge of a project in a particular field, and responsible to a supervisor. Another research problem might involve some fundamental work by one man, and application studies by others using glass models or pilot plants. Each of the projects of the problem might be sufficiently comprehensive so they would be directed by a man whose training and experience made him capable of carrying on this research work. The work of the team would have to be co-ordinated and carefully guided so that the result would be accomplished in the desired research. This would be the job of the supervisor or director who would be directly responsible for the team's performance. This team system is becoming more popular because today's problems are becoming increasingly involved in two or more fields of science and are so interwoven that it is difficult to draw lines between the application of the various sciences. This system compels the co-operation of more than one mind. Although the responsibility for the success of the individual project must rest in one man's hand, the success of the problem depends on his consultation with other members of the team, or work through the supervisor, to bring the problem to complete success.

This method of procedure in the laboratory allows men of initiative, self-reliance, and creative mind to bring out their best efforts in their fields of endeavor. They are responsible for the success of their science field in its phase of the problem. There is some inclination, however, in this kind of a setup, for the individual to hide the knowledge he has gained in order to prevent the other fellow from getting credit for the results. This tends toward lack of co-ordination, which must be carefully guarded against by the supervisor or director, who must constantly try to obtain full co-operation between the members of the team.

The team system imposes a limit upon the men who might be good organizers because of their limited part in the total problem. Men who are good organizers will desire to get out of a team setup and become supervisors or heads of projects. These again are personality problems which must be handled continually by supervisors and directors of research.

Definitions and Laboratory Functions: Fundamental Research

Fundamental research is the qualitative and quantitative investigation of the phenomena and laws of nature. The generally recognized laws of chemistry and physics are the results of fundamental research. The synthesis of new organic compounds comes, broadly speaking, into the category of fundamental research. Determination of the phenomena involved in nuclear disintegration is likewise in this field.

Exploratory Research

Exploratory research is the field of the "try and see" experimenter, the realm of the Edisonian approach. The systematic study of the effect of additional elements on aluminum alloys, or of the effect of chlorination of a series of organic compounds, or of the experimentation of "high lift" devices on airplane wings are examples of exploratory research.

Applied Research

When the available knowledge from fundamental and exploratory research is used in achieving a particular new objective, applied research is under way. Hugo Baekeland found in his preliminary researches that formaldehyde and phenol polymerized to give interesting solid materials. From this beginning he set out to discover ways of making a usable plastic material of construction. He was engaged in applied research. Bakelite was the result. All new materials, devices, or processes, such as plastics, refrigeration systems, and electronic circuits, have probably undergone intensive experimentation by men with a particular objective in view. They have thus all gone through the applied research phase. This phase covers the obtaining of specific, though preliminary, information required for the designers to make the pilot plants or models for perfecting products or systems. Applied research is usually carried through to the first successful working model of a device or process.

Development

This heading covers that work which, using all known information, develops systems or models for the perfection of manufacturing processes and turns out products which will be satisfactory to consumers and which can be sold at a profit. It covers testing, evaluation, styling, market research, and application research.

Factory Control Laboratories

These cover inspection of incoming materials and inspection of the various processes through the manufacturing procedure, whether chemical or mechanical. Chemical analyses might be necessary, or mechanical checks of equipment for performance, noise, etc., at many stages of manufacture before shipment, in order to produce an acceptable uniform product.

All inspection of products or parts must be according to specification; products with an operational function must pass final tests satisfactory to the requirements of research and development.

Production Research

This covers general research on manufacturing processes, and also the fixing of factory standards for the manufacture of apparatus for all types of chemical processes; standard methods of machining and making parts; heat transfer in process work; heat-treating metals, and standard factory processes in general, as required by fundamental research and development. It includes, moreover, industrial engineering in determining factory methods for production, such as the operations required for time study and cost, to decide the final procedure for making a product for a fixed price. Chemical products must be controlled, within the specifications, by whatever intermediate or final analytical stages are necessary.

Application Research

This covers any phase of applying products to consumer uses: the rating or specifications to be applied to products to cover limits of intended use; study of the customer's requirements, as brought in by the research department's service specialists; general field research; determining consumer uses for products manufactured; comparisons of products with those of competitors and customers' reaction to them; and industry standards.

Market Research

This covers surveys of public opinion on a product or determination of the number of possible users of each product to be made; the sizes of equipment that will be purchased; the style that might appeal to the consumer; and the amount of money the consumer is willing to pay for the article.

CHAPTER VI

The Research Program

Columbus, after his first landfall at Hispaniola, might conceivably have spent the rest of his lifetime in exhaustive exploration of the whole island in the study of its climate, its soil, its plant and animal life. Each day would have added new facts to his store of knowledge concerning this one island. He had started his voyage, however, intending to reach the mainland of Asia and, after satisfying himself that this new island was not the continent he was seeking, he pushed on. It is true that he died without ever accomplishing his purpose, but by continuing in the direction planned he gave to the world a whole new continent instead of only one island.

Research is another form of exploration and so, to accomplish the most with the facilities available, must likewise have a definite aim Limitations must be placed on the exploring of ramifications which do not appear to lead toward the primary goal. The temptation is great at times to explore at further length some of the extraneous possibilities which come to light in the course of an investigation, but, except in rare cases, it proves advisable to put them to one side for possible future study. Without a carefully considered purpose and without some limits on its ramifications, research can become a rather meaningless accumulation of facts.

Particularly in industrial research, where the laboratory must not only pay its own way but also show a profit in the results obtained, it is essential that the problems be carefully selected.

Misdirected research may not only be a waste of time and money but may also be destructive of the morale of the research department. A good research worker derives a great amount of satisfaction from the successful solution of a problem, but unless some use is made of

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This chapter by G. O. Cragwall, Director, Technical Service Department, Chas. Pfizer and Co., Inc.

his work a feeling of disappointment follows. Unfortunately, too, management opinion of the worth of the worker is largely based on the dollars and cents value of his results.

Limitations Set by Company Policy

Of primary consideration in planning a research program are the limitations set by company policy. Each industrial concern has, or should have, a particular field, or fields, to which its efforts are confined. This limitation of interest may be the result of one or more of a number of different factors. For example, geographical location may be such that freight charges prevent the economical use of certain raw materials. The technical staff may have special skills suited for research on and production of certain types of materials. These and many other factors influence the company policy with regard to its field of interest.

Effect on Field of Research

Naturally the research director should, on the whole, confine his staff's investigations to problems within the field adopted by his company. This rule, however, should not be followed slavishly since there is always the possibility that the company may find it necessary to broaden or even change entirely its field of endeavor. In such case it would be the duty of the research department to advise on what new products might offer the most promise. The successful research director will carry out a certain amount of investigation in anticipation of such needs, but except in extraordinary cases the amount of work of this character should be small and not far afield.

Effect on Scope of Research

Even after a definite decision has been reached that a certain problem is to be included in the research program, company policy must be taken into consideration in deciding its scope. Some companies prefer, whenever possible, to produce their own raw and intermediate materials, in which case it may be necessary to include in the investigation the development of methods for producing these raw and intermediate materials as well as the finished product.

Other manufacturers, because of lack of room, labor shortages, or for other reasons, prefer to purchase these basic or intermediate products. Here, research should be devoted mainly, if not entirely, to the preparation of the finished product or such intermediates as cannot be obtained on the outside. It is wise, however, not to be bound too closely by company policy in arriving at this decision. Conditions and policies may change, or research may show that such a saving can be effected by producing these basic or intermediate materials that the company cannot afford *not* to do so.

Company policy must also be considered in deciding whether or not the investigation should include derivatives of the particular product to be investigated or uses for it. Here too, there are wide variations in policy among manufacturers. Some prefer to manufacture these subsequent products themselves, while others are not interested. A certain amount of research into the uses to which the product can be put, however, will probably be necessary to assist the technical sales department in developing a market for it.

Sources of Ideas

The success of a research program does not depend alone on proper recognition of the limits to which it should be confined. Without constant and fruitful sources of ideas for possible subjects for research, it must, of necessity, languish. Sources of such ideas are many and varied, but it is necessary to recognize where they may be found and to develop a system whereby they may be tapped.

Scientific Literature

One of the main sources of ideas, both for new research projects and for means of solution of those already under way, lies in scientific and technical literature, including patents. It is absolutely essential that the research department keep thoroughly abreast of current developments in the fields where its interests lie. This presupposes a thorough familiarity with past developments. In accomplishing this the library staff or information department can be of invaluable assistance. Modern literature is so voluminous that, if the research worker attempts to read everything published which might be of interest to him, he will find that he has little or no time for actual research. A competent information department can assume a large part of this load by reviewing current literature carefully and furnishing abstracts of articles which may be of interest.

We must emphasize, however, that the research department should not rely upon such abstracts as its sole source of information on current developments. The original article should be read if the abstract suggests that it contains valuable information. No matter how capable an information department may be, it cannot recognize everything that might be helpful; so the research department should review such publications as experience has shown to be most fruitful in ideas and information.

Where possible, such an information department should be separate from research, since it can serve other divisions of the company as well. If the company organization does not include such a department, the research director should give serious consideration to assigning such work to staff members who have shown an aptitude in that direction.

Management

The literature, both current and past, is by no means the only source of ideas in the establishment of a research program. Many such sources lie within the company itself and must not be overlooked. Management should be an important one of these, if the company is to prosper.

Of course, the program must be discussed with the proper executives and have their approval before it can be initiated, but management should not confine its activities in this connection merely to deciding which of the ideas advanced should be followed up. Company policies are established at this level and consequently, if progress is to be made, ideas in which policy plays a part should, in general, arise with management, particularly if any radical departure from previous policy is involved.

Such ideas should be discussed thoroughly with the research department and there should be agreement that they have possibilities before including them in the research program. Management should have sufficient confidence in the abilities of its research staff to be guided by its recommendations relative to the possibilities of its own ideas.

Production

Production must not be overlooked as another source of ideas. No other department of the company is as familiar with manufacturing procedures and the difficulties which arise from time to time. As a research program should include not only the investigation of new products and processes but also the improvement of present ones, it is production that should be best able to advise regarding the latter. There exists, however, the possibility of "not being able to see the forest for the trees," and in consequence someone not directly connected with an operation may see needs for improvement that may not appear to those connected with the process day after day. For this reason, it is well for the research department to maintain close contact with plant operations. One means of accomplishing this is to appoint one or several members of the research staff to act as a liaison between the two.

Sales

The sales department also is often a prolific source of ideas. Many of these ideas, naturally, deal with product improvement designed to make the salesman's job easier. This department can be relied upon for information about any superiorities which competitive products may have and for ideas regarding desirable improvements in the company's own products.

An alert sales organization, however, will not confine its suggestions merely to product improvement. Through its contacts with customer purchasing departments and technical personnel, it can derive many ideas concerning new possibilities. It is in an excellent position in which to learn of unfilled needs among the customers and to sense new trends. Usually it is not possible to maintain as close contact between research and sales as between research and management or production, but means should be set up whereby good ideas are not lost before they can be evaluated.

All such ideas, suggestions, and even gossip, should be incorporated in the salesmen's reports. In turn, the sales manager should pass them on, through the proper channels, for evaluation both by the management and by the research department. Periodic attendance of sales meetings by representatives of the research department may also prove quite helpful in establishing the research program by furnishing first-hand information on how research can best serve sales. On the other hand, visits by the sales staff with the research department serve to awaken the salesman to the fact that the research worker is just another human being, with limitations in what he can accomplish. Such contacts enable each to visualize the difficulties with which the other is beset and show the need for cooperation.

Technical Service

A technical service department, being composed of technically trained personnel, and being as a rule rather closely connected with research, should be of particular help in formulating a research program. It is in close contact with the technical personnel of the company's customers and consequently is in an excellent position to furnish ideas as to the lines along which research should proceed. Its opportunities for learning of product improvements needed, new products, new uses for old products, trends in industry, etc., are even better than those of the sales department and have a more truly scientific background. The need for close contact between technical service and research is obvious.

This brings up the question of the position which technical service should occupy in the company organization. Policies differ widely in this respect, and undoubtedly no one answer is applicable to all cases. Often this service, placed under the sales department, may attain maximum customer service, but to the exclusion of the development of markets for new products and of new uses for old products. In other organizations, where technical service is part of the research department, there is danger of new products being emphasized at the expense of customer service. Some companies seek to avoid the two horns of this dilemma by having an independent technical service responsible to neither sales nor research. Whatever the policy, this department should be alert for new ideas and should be consulted in establishing the research program.

Meetings of Technical and Scientific Societies

Attendance at meetings of scientific and technical societies by members of the research staff may also result in ideas which may be incorporated in the program. Science stagnates without an interchange of knowledge and often a scientific paper or a conversation with a colleague in an entirely different field may be most fruitful. There is a story that the idea which led to the development of one of the important types of synthetic rubber resulted from a paper, read by a university professor, on a topic which, except to a highly alert mind, seemed to have little or no connection with such a product.

As not all men have the imagination to derive ideas from such contacts, the research director should himself attend such meetings whenever possible or should delegate this duty to able members of his staff. This does not mean, of course, that other research workers should be denied this opportunity for inspiration and for keeping abreast of developments. They should be encouraged to attend such meetings whenever possible, and to become acquainted with others in their own and other industries.

Project Initiation and Scheduling

The next step in setting up the research program is a screening of the ideas, separating them into those which should be investigated at once, those reserved for future incorporation, and those which seem to offer little promise. Naturally this does not mean that the flow of ideas should then be allowed to dry up at the various sources. On the contrary, it is essential that they be continued, although too frequent revision of the program is inadvisable.

In deciding on the projects to be investigated the director must keep in mind the limitations of his staff. For example, progress on a problem involving the development of special alloys will be slow unless a trained metallurgist is available. One solution would be to add a metallurgist to the staff, but before doing this one must decide whether or not the project is of sufficient importance to warrant this step and whether such a research worker can be used on other projects, present or contemplated. In general, the addition of men of special skills should be avoided unless it is felt that there will be a continuing need for their services. The staff should be of broad enough experience, however, to be able to handle efficiently the problems which should arise in the program outlined. The success of any research program depends not only on careful planning and selection of projects but even more on the qualifications of the research staff available for carrying it out.

Assuming that the projects to be included have been selected and that a staff of sufficiently diversified abilities is available, the next decision is that of the proper division of the problems selected among the research staff. Careful consideration must be given to each project and a decision be reached as to the necessary number of research workers. Often a problem can be separated into a number of more or less closely related phases which can be investigated independently or semi-independently, so that more rapid progress can be made if it is divided among several members of the staff. In other cases this is not possible and only one man or a small group can carry out the research without duplication of work. Each project should be considered separately and a decision reached as to the number of men who can handle it most efficiently. Simple arithmetic then determines whether or not the sum of the men needed for all projects equals the total number available. Unfortunately this sum often proves to be greater than the staff and the director must then review the whole matter and cut his pattern of men needed to suit his cloth of men available.

To accomplish this it may be necessary to reduce the size of the groups assigned to specific problems, but a better solution, usually, is to assign more than one problem to individuals or groups. In any research there occur periods during which little can be done; these may be due to waiting for tests to be completed, for necessary apparatus or equipment, for inspiration about what to try next, or for a myriad other reasons. If two or more projects are being carried out simultaneously, these waiting periods of one project can be devoted to work on another. A happy solution may be to assign both a long-term and a short-term project to a research unit. Generally time is of less importance in the case of the long-term research and it can be fitted into the gaps in the more pressing short-term project.

The director next must decide which of his staff are to be assigned to each project. For this it is highly important that he have a thorough understanding of their individual training, experience, and capabilities. In a large organization it may be impossible for the director to know all members intimately enough to make this selection, and this duty must therefore fall on his assistants. However it is handled, a wise selection of personnel for the individual project plays an important part in the success or failure of the program.

Periodic Review of Progress Made

Obviously it is impossible at the start of a research project to predict the length of time which will be required for its successful completion—particularly if a "flash of genius" is to be required—or to arrive at a definite decision on the cost of the materials and equipment which will be used. If, however, the expenditure of time and money is not to be out of proportion to the possible profit which may accrue to the company from its successful conclusion, such estimates must be prepared. In this, previous experience with similar projects often proves an invaluable, though not infallible, guide. Lacking such help, the best procedure usually is to carry out a short preliminary investigation which will indicate what difficulties may be expected and from which an estimate of the time and expenditures involved may be formulated. A considerable part of the director's worth to his company depends on his success in preparing, and having prepared, such estimates and schedules.

Even though dates are set on which it is estimated that each project in the research program should be completed, it goes without saying that it is quite inadvisable to wait until those dates to review each project. Much useless expenditure of time and money can be avoided by setting up schedules for periodic reviews. These should not be at such frequent intervals that it is difficult to form a true picture of actual progress, but they should be sufficiently frequent to prevent prolonged work on projects whose continuation cannot be justified. In such reviews it is well for management, the research director, and members of the staff responsible for the investigation to take part. All should have a chance to express opinions as to the progress which has been made and the possibilities of successfully completing the work. The temptation is great, particularly among those actually engaged in the research, to feel that, even though the project may have apparently "bogged down," just a few days' more work will bring to light a solution to difficulties which seem insurmountable at the time. On the other hand, management may feel that there is no point in further expenditure and it may be difficult or impossible to come to an agreement. Naturally, management will have the final say, since it is the company's money which is involved, but hasty decisions in terminating a project should be avoided.

Such reviews should be supplemented by progress reports, prepared by those engaged in the investigation and submitted to the director. He in turn may either submit these to his superior or prepare digests for submittal. The frequency of such reports varies among different organizations; in some cases they are weekly, in others biweekly, monthly, or at longer intervals. Because of the wide variation in research projects and in the speed at which they may progress, experience must dictate the proper frequency for such reports.

Careful evaluation of these reports will indicate whether or not satisfactory progress is being made and may suggest possible methods of attack which have been overlooked. Even though a regular schedule of project reviews has been set up, such progress reports may indicate the need of having such a review even though the scheduled time has not arrived. This is particularly the case when the investigation seems to be making little or no progress.

Use of Supplementary Facilities

Earlier in this chapter we have mentioned difficulties which might arise in setting up a research program which needs personnel of specialized training and experience. As pointed out, it may not be advisable to add such personnel to the research staff because of the limited amount of specialized work that may be required.

Fortunately it is possible for the industrial research laboratory to avail itself of the services of such personnel, either in a consulting capacity or as they are found in outside laboratories. Excellent consulting laboratories, covering practically the whole field of research activities and with personnel having the requisite specialized training and experience, exist today. Naturally such laboratories must operate at a profit, but if the proper choice is made it often proves to be more economical to "farm out" research of this type than to add additional personnel or train some of the members of the staff through actual experimentation.

Unless the consulting laboratory is well known to the industrial laboratory through previous contacts, it should be investigated before any definite arrangements are completed. Such an investigation should be designed to determine whether its personnel has the necessary training and experience, whether it has the equipment which will be needed for the investigation, and whether capable supervision will be available. The good consulting laboratory recognizes that such investigations are needed and facilitates them by literature describing its personnel and equipment and by welcoming inspection of its facilities and interviews with its supervisory staff.

Once final arrangements have been made, the consulting laboratory will wish to assume charge of the investigation assigned to it. Any other system would probably be unworkable, except in very special cases. The industrial laboratory, however, should maintain close contact not only through progress reports submitted by the consulting laboratory but also through consultations with its supervisory staff. Such meetings are mutually beneficial, insuring that the consulting laboratory properly understands the problems assigned to it and that the industrial laboratory is kept thoroughly informed on the results obtained.

Arrangements for specialized investigation of this type are also frequently made with institutions of a public or semi-public nature, such as universities, medical and other research institutes, laboratories sponsored by certain industries, etc. It should be recognized that those conducting such research probably will not be able to devote all of their time to it. At universities they generally are students engaged in obtaining advanced degrees and at other institutions they may have other duties. Because of this, progress may not be so rapid as it would be in an industrial laboratory and it is well to recognize this, if misunderstandings are to be avoided.

Careful consideration should be given to secrecy requirements and possible patentable results in arranging for outside research projects of this nature. With consulting laboratories, secrecy requirements generally can be settled without undue difficulty. Policies in regard to patents, however, differ somewhat among such laboratories and there should be a written agreement as to the ownership of any patents before final arrangements are made.

Universities, and other institutions supported wholly or partially by public funds, as a rule must insist on the right to publish results obtained in their laboratories. Under these circumstances secrecy cannot be maintained. Policies in regard to patents vary widely. Some institutions insist that results of investigations conducted in their laboratories cannot be patented, others that such patents are to be the property of the institution. Some agree to joint ownership. Still others allow the donor of a fellowship full ownership of any patents resulting from the investigation. The need for a thorough understanding before making final arrangements is obvious.

Another case in which the research program may profit by availing itself of the services of an outside laboratory is where the use of expensive equipment, not ordinarily used in the industrial laboratory, is required. A project under investigation may involve, for example, the use of an electron microscope, and, as far as can be foreseen, little further use could be made of this expensive piece of equipment. Under such circumstances the more economical procedure probably would be to pay the required fee for such examinations by consulting or institutional laboratories where this equipment is available.

To summarize, the research program may benefit through arrangements with outside laboratories or consultants in cases where specialized knowledge or equipment, not ordinarily needed, is required. If a commercial consulting laboratory is used, secrecy requirements can be met, and usually satisfactory arrangements made regarding patentable results. Although the close contact maintained where the research is carried out in the organization's own laboratory is lacking, there should be no great difference in the speed with which results are obtained.

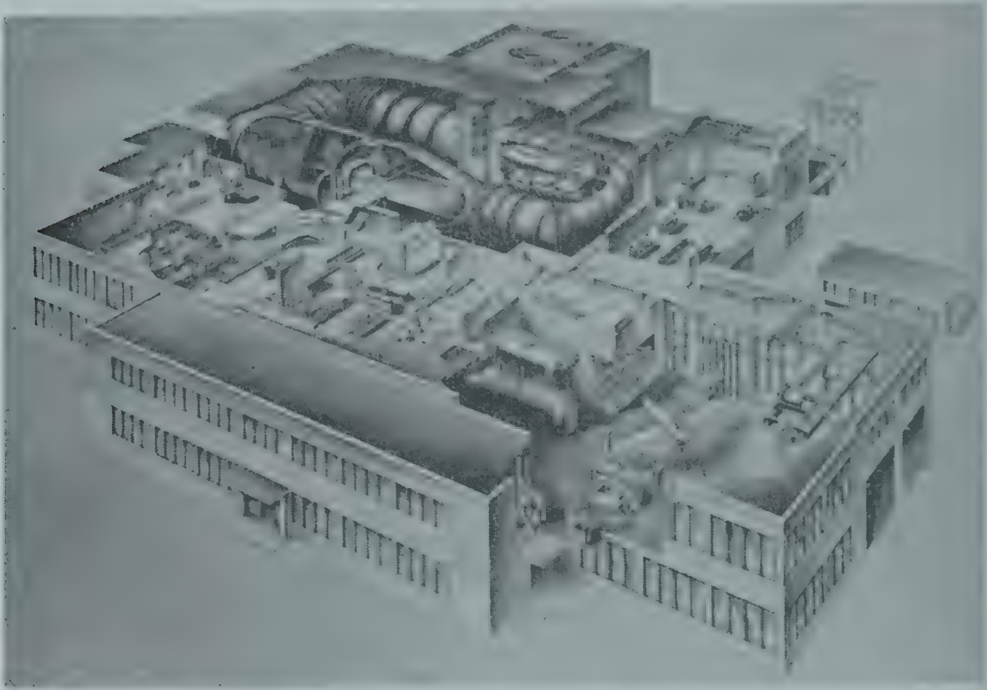

PHOTO. 13. The Cornell Aeronautical Laboratory. Research foundations can often serve by making expensive and specialized equipment available to industry. (*Courtesy of the Cornell Aeronautical Laboratory.*)

The expense of such investigations may be slightly less if they are conducted in an institutional laboratory, particularly if use is made of graduate students. As a rule the investigation will proceed more slowly than in a commercial laboratory and difficulties may arise if secrecy is necessary or if patentable ideas result.

One point which should not be overlooked in giving consideration to the university laboratory is that the individual company and industry as a whole are dependent on such institutions for scientifically trained personnel and derive indirect benefit in contributing to their support. It also often happens that through fellowships it is possible to make valuable additions to the company's scientific staff.

Proper Balance between Long- and Short-Term Projects

A final point to be considered in deciding on a research program is that of maintaining a proper balance between long- and short-term projects. Usually both types of problems exist and, if care is not exercised, the program may become unbalanced in either direction.

Long-range projects are generally designed for the development of new products, without which an organization will stagnate. They also lend a certain amount of flexibility to the research department. Time is not of the utmost importance, and when emergencies arise, it may be possible to divert personnel from them to more pressing investigations.

On the other hand, tangible results are, of necessity, slow in coming. If a program consists entirely, or mainly, of such projects, management may begin to doubt whether or not the research laboratory is paying its way. The morale, and also the salaries, of the research staff may also be affected adversely by a paucity of results. An even more serious danger is that insufficient research may be devoted to product improvement and reduction in manufacturing costs and, in consequence, the company may lag behind its competitors in the case of items presently being produced and upon which present profits are dependent.

Short-term projects are designed for quick results and a research program consisting wholly, or mainly, of such projects will enable a research department in a comparatively short time to "point with pride" to a long list of completed problems. Also, quite often, such problems deal with product improvement or reduction of manufacturing costs, so that short-term projects enable the company to maintain a favorable competitive position in so far as current products are concerned.

Progress, however, results in the appearance of new products as well as in the improvement of old ones. A company whose research program has been devoted to short-term projects may some day find that although its products are better and less expensive to produce than similar ones of other manufacturers, they are, unfortunately, being replaced by new products which have been developed.

The need of proper balance between short- and long-term projects was strikingly illustrated in the course of the American dyestuff industry during World War I and some ten years or so thereafter. Before this war the United States was almost entirely dependent on Germany for its dyes. When this source was cut off prices ran to fantastic heights and there was a wild scramble to produce dyes in this country. The seized German patents gave directions for their production, so that, generally, only a short research project was required before production could be started. The demand was so great and prices so high that it made little difference how efficient the process was; the main need was for production as soon as possible.

Gradually, however, supply began to catch up with demand, prices began to drop, and costs began to assume more importance. The research of some producers had consisted entirely of short-range projects designed solely to get as many different dyes on the market with as much haste as possible. Others, with greater foresight, had included in their research programs projects of longer range intended to develop more efficient processes for dyes already being produced and in some cases also to develop entirely new dyes of superior properties or for specific needs.

Competition continued to become keener and, as it did so, the inefficient producers were weeded out, leaving the field to those with lower costs and superior products. By this time the patent literature had been quite thoroughly combed, so that short-term research was devoted mainly to product and process improvement, while long-term projects were devoted to the development of entirely new dyestuffs. As these appeared upon the market, they often replaced the older dyes and once again the producers whose research programs were all short range were placed at a disadvantage. Further weeding out followed and, as a result, present-day producers are those who have arrived at a proper balance between research on new dyes and that devoted to the improvement and utilization of those already being produced.

As has been pointed out, a proper balance between long, and short-term projects also can lead to increased efficiency. Both types can be assigned to a research unit, and time which otherwise would be lost because of unavoidable delays in one project can be utilized in working on the other. This may also serve to prevent among members of the staff possible dissatisfaction at being assigned to problems from which tangible results will be slow in coming.

Occasionally it may be found that a large number of long-range projects cannot be avoided. Under such circumstances it may prove advantageous to arrange for the prosecution of some of them in outside laboratories, in order to prevent a lack of balance in the program. Where more or less "pure" science is involved, institutional laboratories may be preferable, but for strictly commercial projects, consulting laboratories may be the better choice.

Where this proper balance between the two types of projects lies will vary widely, but if the research progress is not to suffer, it must be determined and maintained for each organization.

In this chapter an attempt has been made, in addition to pointing out the need for proper balance between long- and short-term projects, to offer other suggestions for the establishment of a research program. These have included the limitations required as a result of company policy, sources of ideas, means of maintaining proper contact with the various projects, and the possibility of making use of supplementary facilities such as outside laboratories.

CHAPTER VII

Selecting Projects for Research

The director of one of our great research institutes has said, "One of the most difficult jobs any research director in industry has is that of selecting a problem which, if properly pursued, through research, could yield dividends to the company." There are many others who can testify concerning the same quandary.

Since the selection of projects is an activity which is not subject to an exact analysis, its characteristics are more those of an art than a science and it is obvious that the experience of a number of successful laboratories could serve as a valuable guide to all research directors, who are continuously faced with the problem. With these thoughts in mind the author embarked upon a questionnaire campaign to obtain information on the approach and experiences of a number of outstanding industrial research laboratories. Replies to the questionnaire were received from 121 laboratories—about 70 per cent of those contacted. The laboratories replying represented organizations ranging in size from 5 to 3000 personnel employed. The research personnel involved approximate 17,000 technically trained persons and represent 22 different industries and organizations, as follows:

- Abrasives
- Advertising
- Chemical
- Consulting
- Containers
- Distilling
- Electrical
- Electrical Communications
- Engineering
- Explosives
- Food
- Glass
- Governmental
- Metallurgical
- Oil
- Paint
- Paper
- Pharmaceutical
- Rubber
- Scientific Instruments
- Soap
- Textile

This chapter by C. G. Harrel, Director of Research, Pillsbury Mills, Inc.

The organizations have been kept anonymous, but from the range in size and activity it can be seen that they represent a good cross section of the industrial research structure of the country. The results of this survey thus represent a well rounded view which has proved valuable over a number of years of experience. The questionnaire which served as the basis of this survey is given in the appendix of this chapter.

Planned Selection of Research Projects

The questionnaire survey indicated that 63.4 per cent of the research organizations have a definite plan for selecting their research projects.

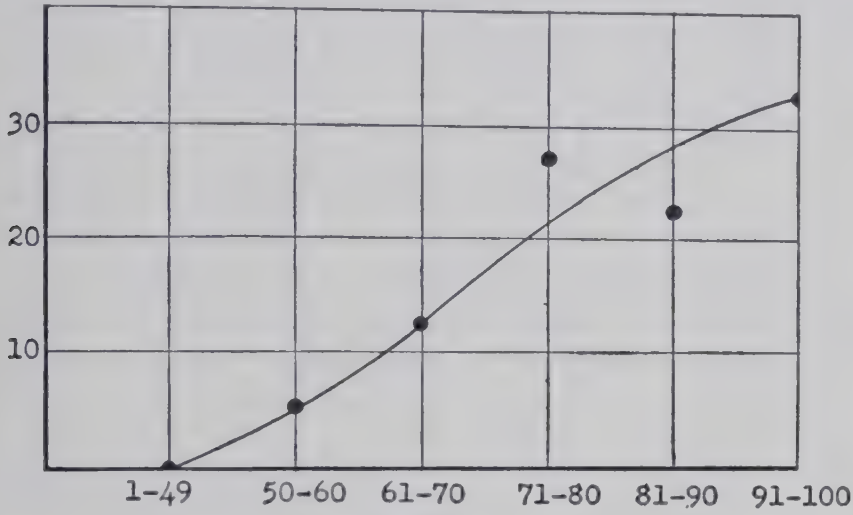

FIG. 9.

Figure 9 shows the relative percentage of adherence to the adopted plan in the instances of the 63.4 per cent having specific plans. It is to be noted here that only approximately 30 per cent adhere to these plans between 91 per cent and 100 per cent of the time. The lack of complete adherence to the proposed plan is an earmark of sound judgment. Any plan proposed for choosing research projects must be broad enough and possess sufficient freedom to permit functioning in various types of emergencies. It is probably with good reason that some organizations become opposed to rigid and unyielding plans for selecting research projects. A national manufacturer of chemicals has the following to say: "Our research is not handled according to the static plan of procedure. It is in the hands of a group of alert, competent directors, who look after the company's interest in research matters and operate with a degree of freedom and flexibility just as do other executive officers of the company."

The difficulties encountered in selecting projects for research resemble, in a great many respects, the problems of a military commander. Long before his major military engagements he must collect information and evaluate the resistance to be encountered; he must choose that particular method of attack which will make the resistance most vulnerable; he must see to it that he has the right type of troops and fighting equipment; last, but not least, the *esprit de corps* must be high and the attack must be precisely timed.

In an army, one of the rudiments is organized discipline. In research, a clear outline of company policies with their aims and hopes of achievement will go a long way toward simplifying the problem of choosing projects for research. An important contributor says: "As I see it, the greatest aid that can be given to an industrial research department is a clean-cut statement of company policy defined by the executive officers. This policy should state a goal of company progress and the desired means of achieving it. Therefore, it comprehends the way in which research is expected to contribute to the welfare of the company." This clear-cut policy statement will greatly facilitate the choosing of research projects as well as the entire research program.

The research executive who selects research projects has somewhat the same problem as the well known New York lawyer, Max Steuer, who had a record of having won 95 per cent of all the legal cases that he handled. Mr. Steuer, on being asked why he won such a high percentage of his cases, replied that it was very easy—he had such a sufficient number of cases offered him that he could select the ones that he was almost certain to win. Dr. Harold K. Work, in his course of Management of Research and Development in New York University, says,

> If the research man approaches his problem in much the same way and judiciously picks from the many available problems those on which he is reasonably certain of success, the path from the research laboratory to the factory will be very much eased. Unfortunately, the problem is not always so simple, but the point I wish to emphasize is that a proper selection of subject matter will go far to ensure successful completion of the research and development work.

This selection in basic or fundamental research and in partially applied research is frequently limited. It is interesting to note the following quotations from those who answered the questionnaire:

> 1. From a laboratory employing 100 research workers: "The situation here has always been such that we have had far more pressing problems to investigate than we can undertake with the staff available. The result has been that we have picked those which seemed to offer the best and quickest financial return and don't worry about the others."
>
> 2. From a laboratory employing 71 research workers: "In general, we endeavor to select projects which are susceptible to a rather definite solution with the hope that the value of this research can be demonstrated on a dollar-and-cent basis."
>
> 3. In a laboratory whose research developments have been outstanding, and whose director has received the Osborne Medal Award, we find another extreme: "It is a constant irritation and disappointment to me that so few ideas are presented to us from which to select. In only two instances have we received ideas worthy of consideration."

Somewhere between these two vast extremes, undoubtedly, lies the average operating research laboratory or institute.

Classification and Distribution of Projects

In choosing a new project what should be looked for to judge whether or not that project is worthy of being considered? An answer to this has been given by Charles F. Kettering[5] as follows:

> The project should do one or more of the following:
>
> A. Reduce cost of production.
> B. Reduce operating cost to the user.
> C. Increase the utility of the product.
> D. Increase its sales appeal.
> E. Produce new business.
> F. Determine technical information contributory to some other project.

Kettering then adds to this outline the following: "Testing aims to improve a new product, research aims to find something we need but have not. All research must partake as much of economic horsesense as it partakes of scientific principles."

Before we proceed further with the discussion of choosing research projects it is well that some system of classification of research projects be established. Dr. Haskins in his discussion on "The Selection of Problems for Research" in the course of management of research at New York University divided research as shown in Figure 10.

TYPES OF RESEARCH

Group No.	Type	Field of Activity	Typical Problem	Laboratory Representing Type
1	Pure Research (Basic) (Fundamental)	Selected only because they seem basic to the particular field in which the laboratory was primarily interested, or an allied field.	Nuclear Research (pre-atomic bomb)	Carnegie Institution, the Rockefeller Institute and academic laboratories in general.
2	Partially applied Research	Deals with problems in which the selection has gone a little further and pointed to a specific gain of knowledge to which it was hoped that the research might lead.	The development of the X-ray tube	Research laboratories of the General Electric Co. and the Bell Telephone Laboratories.
3	Fully applied Research (Practical) (Applied research)	The effort is directed to gain specific knowledge for a specific end.	The development of ammonia synthesis	Works Laboratory of the General Electric Company
4	Engineering Research	Deals primarily with the overcoming of difficulties in or the further development of a process.	Perfection of the mercury-boiler turbine	

FIG. 10.

Group 1 involves what he has chosen to call "pure research." This may likewise be termed fundamental or basic research. Other than to indicate the general field or trend of such basic research, the selection should primarily be left to the men working in this field. Group 2, which is "partially applied research," undoubtedly requires co-operation with other departments of the organization in which it is being conducted. Groups 3 and 4 require intense co-operation in making decisions of choice on projects with the operating, sales, and executive branch of the organization interested in the specific research.

Research projects may be classified according to period of duration as shown in Figure 11. Short-term projects usually require from two to six months with an expenditure in the neighborhood of

$500 to $1,000, and the choice should be left almost entirely with the research laboratory.

One director of research in a well-recognized food research foundation which has contributed to this survey writes as follows: "It is within my discretion to admit minor or short-term projects to our program, subject to review before higher authority should the source of the request disagree with my decision. It is within this category that we do our gambling and exploratory probing." These short-term projects may be used in collecting information and data in assisting the research director to determine whether or not a proposed project is worthy of recommendation for intensive research investigation. They may be compared directly with the observations, measurements, and data collected by a diagnostician prior to his recommendations for medical treatment. The miscellaneous projects shown on the bottom of this chart (Figure 11) are of even minor importance so far as their selection is concerned. The choice of these projects should be largely within the realm of the research department.

Classified as to Period of Duration

Group No.	Name	Possible Period of Duration	Approximate Salary Budget	Expectancy
A	Short-term	Two to six months	$500–$1,000	Quick results (percentage successfully completed will be materially lowered if exploratory investigation is included under short-term.)
B	Intermediate term	Six months to one year	$1,000–$10,000	Reasonable assurance of success
C	Long-term	One to several years	Unlimited	If successful they usually hit the "jack-pot."
D	Miscellaneous	Sequence of projects requiring from one to several weeks each	Very small percentage of total expenditure if confined to analytical and assay methods.	Improvements of methods, minor improvements in processes and products, if the latter are included.

Fig. 11.

Dr. C. L. Gabriel [2] states:

> A research department must produce results which bring additional profits to the company which supports it. For this reason, at least half of the personnel should be working on relatively short-range problems which show promise of being carried to successful conclusions within two or three years. This makes possible a fairly steady flow of completed new projects while experiments on longer-range problems are being carried out in the laboratory.

Although time classification does not coincide with that specified in our chart, the thought of the necessity of having some short-range problems capable of being successfully completed is deemed advisable by this executive.

Groups B and C which constitute the intermediate and long-term projects are major undertakings and the director of the research department of a large research laboratory advises the procedure in his organization as follows: "Major, or what are likely to be long-term, projects are not admitted to our program unless approved by the committee consisting of the President, the Vice-President in charge of Merchandising, the Vice-President in charge of Manufacturing, and myself." Other schemes of selection will be shown later in this chapter, but the above amply illustrate the co-operative manner in which this procedure should take place.

Miscellaneous projects (those which result in no definite return to the company, such as preparation of magazine articles, collaborative research, etc.) should not be called to the attention of other departments for official action, and co-operative choosing should begin with the intermediate and long-term projects.

In order to be of assistance in preventing an undue proportion of either short-term, long-term, continuous, or miscellaneous projects being chosen, Figure 12 gives the average distribution of research man-hours on such projects among well-organized laboratories.

As to the relative distribution of research, the following, from the research laboratories of an electrical organization, is cited: "Some 75 per cent of the research man-hours are then assigned on the basis of these priorities. The remaining 25 per cent of the time is left to the group leaders to spend as they see fit regardless of management's priorities, but on listed problems." This is in close agreement with the results as expressed in Figure 12 wherein 29.4 per cent of the total time allotted is for the short-term projects. Emphasis is placed upon the encouragement of individual initiative in the research worker.

A large research organization offers the following:

> Your questionnaire has stimulated me to plan a comprehensive study of our experience during the last six years to help in deciding future policy. The answers which I have given in your questionnaire are based solely on opinion and will probably be modified by the comprehensive survey which I plan. I wish to amplify my answers to your questionnaire as follows:
>
> As a result of several years of careful scrutiny of projects, we have arrived at a definite plan, procedure, and policy for the selection of our development projects. We are limited to certain fields and we select a certain proportion of short-range and long-range projects and a certain proportion of projects with no pay-off and projects with good prospects of financial return. There are exceptions, usually where we wish to explore new possibilities on which the information is too meager to make any accurate prediction on either future success or prospects for financial return.

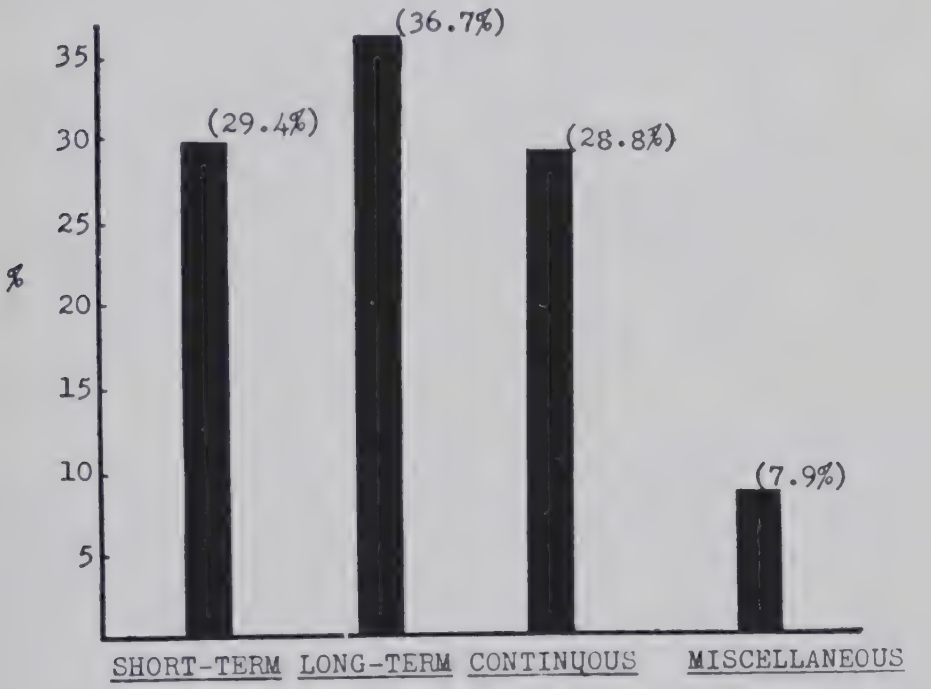

Fig. 12.

Projects Resulting in Satisfactory Solution

As with quarterbacks, it would be logical to be interested in knowing whether it is a long-end run or the short-buck through center which is ultimately successful. No consolation is found in the comparison given in Figure 13, which seems to indicate that the chances are about equal in the solutions of long-term and short-term projects chosen.

Here it must be remembered that when exploratory research is employed as a prerequisite in making the choice, it is often classed as a short-term project which greatly decreases the percentage of successful terminations of the simpler or short-term projects.

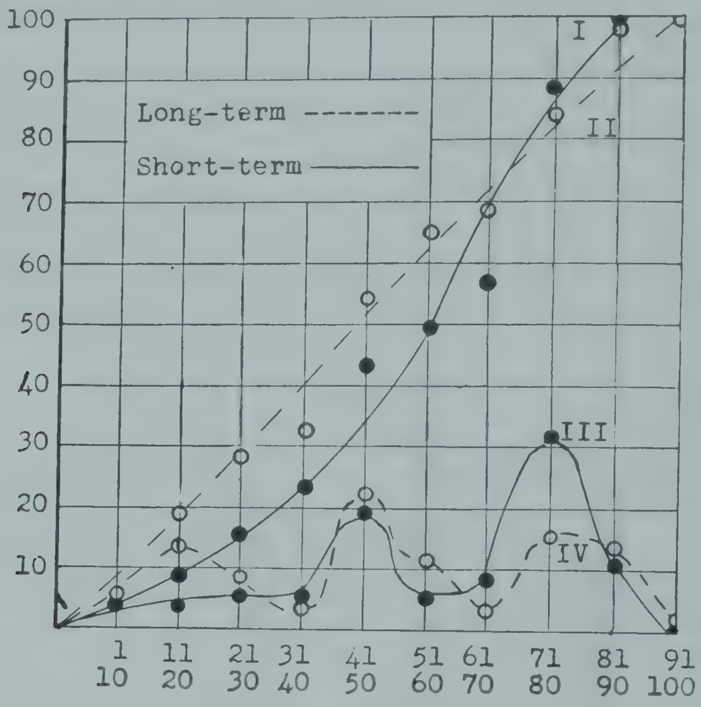

FIG. 13.

Personnel and Morale

In military operations, as in research, it is essential that some battles be won, or the spirit of the troops will deteriorate. The research laboratory that has a low record of accomplishment in solving projects is one that is exceedingly likely to have a low degree of enthusiasm. From a psychological standpoint it is often well to choose a sufficient number of problems that seem reasonably certain of solution to keep morale high enough so that a positive potential exists at all times. One of our contributors suggests: "I believe it is an excellent idea to break the monotony for the research man on long-term projects by giving him a short-term project within his field and one that seems sure of a practical solution." Another contributor volunteers as follows: "We point out to some men engaged in long-term research the fact that it may be some time until their results can be put on an operating basis. Consequently, we endeavor to keep their morale up by occasional meetings and encouragement on their work."

Dr. Karl T. Compton,[1] President, Massachusetts Institute of Technology, has the following to say:

> Three new trends have come into industrial attitude toward research:
>
> 1. Increasing interest in fundamental research.
> 2. A more liberal interpretation of company policy.
> 3. Increasing tendency to co-operate with other companies in the industry or with the universities.
>
> While every industrial research laboratory must in the last analysis justify itself to the board of directors by its contributions to the business of the company through development of new products or improved methods of production, nevertheless it has been recognized by the most forward-looking companies that it is appropriate for them to engage in a certain amount of fundamental research which does not have an immediate practical objective in view. Reasons for this:
>
> 1. *Highest type of productive research man cannot be retained unless he has some opportunity to work on subjects which incite his scientific ambition and curiosity.*
> 2. Frequently ideas having a practical application arise from fundamental research.
> 3. Company may wish to keep well advised concerning new developments into which they may wish to enter in a major way when an attractive opportunity presents itself.

Here again is seen the necessity of maintaining the interest of the individual research worker by providing projects of specific interests.

It is vital that the individual conducting a specific investigation be intensely interested, personally, in the subject under investigation. If the manpower is limited, such a consideration has a bearing upon the selection. This is true in industrial as well as academic or fundamental research.

Dr. H. B. Hass[4] of Purdue University and Purdue Research Foundation says: "Before attempting the solution of a problem originating from a source external to the University, the Foundation assures itself that it is of vital interest to one or more staff members, is of genuine scientific importance, and has a reasonable chance of success." This well illustrates the fact that interest of the investigator and likelihood of success are paramount considerations in choosing projects.

Some research workers, like men in other professions, such as surgeons, lawyers, doctors, and musicians, are extremely temperamental. The writer well remembers an excellent, highly qualified research man who remarked after a visit of a number of sales managers that all salesmen, like kittens, should be disposed of by drowning. This is a distinctly temperamental and one-sided view. This man worked exceedingly well on projects which were to his liking and on others he would do only average work.

In extremely large research organizations a lesser amount of attention is undoubtedly given to selecting projects to fit these highly specialized workers. In such organizations there are always a number of research men who are well qualified and, through experience, have learned to play several positions on the "Eleven." Sometimes far too little appreciation is given these all-around performers.

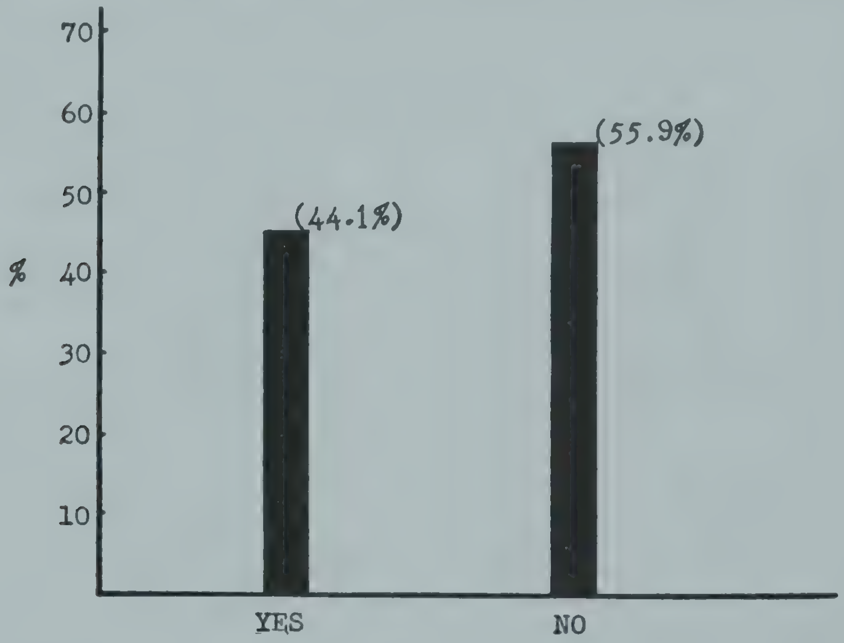

Fig. 14.

Dr. William A. Hamor,[3] the Assistant Director of Mellon Institute, has the following to say:

> Researchists who are kept in a state of good morale do not readily lose interest in what they are doing. They tend to feel they are joined together by a common purpose and common responsibilities. A capable research man may be a small part of a laboratory; but if he has the right qualities, the right direction, the right atmosphere, the laboratory will be a great part of him. He always takes to work his heart and mind with all his professional equipment. Only *enlightened, friendly,* and *honest leadership* in action can bring into existence and keep the *esprit de corps* that distinguishes the happy, brisk, continuously advancing organization.

In smaller laboratories where specialized personnel are limited, the choice of selecting a research problem appropriate to the individual is most important. If a problem is chosen which does not harmonize with the tempo of specialized research individuals and there are no research men of all-around ability in the organization, it would be the most profitable procedure in the long run either to obtain additional personnel for the specific problem or to conduct the research in outside laboratories.

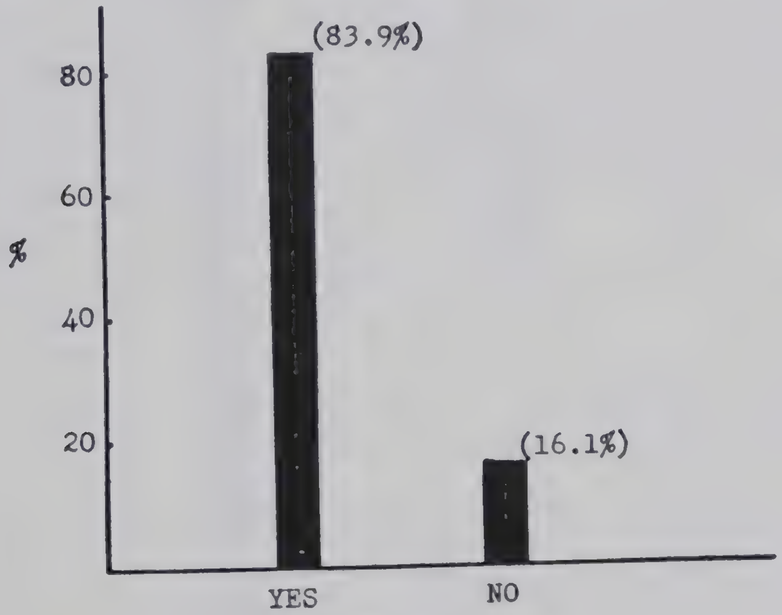

Fig. 15.

In answer to the question, "Are research projects chosen to fit the specialized personnel of the research department?" Figure 14 shows that 44.1 per cent of the laboratories do recognize this in making their choice of projects.

Figure 15 shows that 83.9 per cent of the research organizations choose the project and then later acquire personnel suitable for the specific project, if they are not already available.

Figure 16 shows that 57.5 per cent of the organizations choosing research projects recognize the importance of sustaining individual initiative and morale by choosing projects that have great possibilities of solution and distributing them to personnel concurrently engaged in the solution of long-time projects. Nothing can be more disheartening than to have a research individual or department work diligently year after year and yet accomplish few worthwhile results that can be utilized by the organization as a whole.

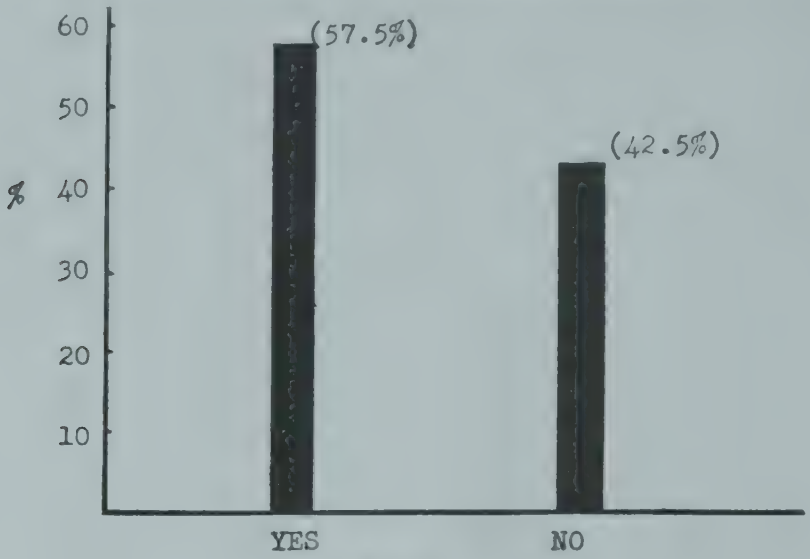

FIG. 16.

Timeliness of the Project

Dr. Harold K. Work states that

> The development should also be timely. Regarding this point, there is little doubt that many fine research studies have proved to be failures because of the fact that they were developed too early. This is borne out by the fact that many great inventions have been attempted several times before they finally succeeded. In a similar way it probably could also be said that new research developments can come too late. Research developments have a certain period of usefulness after which they are often replaced by something new.

It is thus observed that the choosing of projects must be as precisely timed as a well-planned military maneuver. Not only must they be precisely timed—they must also be the correct project, properly developed, and available at a utilizable place. Dr. Roland P. Soule [6] emphasizes these facts:

> The most important thing of all is obviously to choose the right project. It is before we actually start any experimental work that consciously or unconsciously, we do the most to set the odds either for or against ourselves. Unfortunately, however, the choice of the project is often more difficult than its subsequent solution. A rare combination of business vision and technical insight is required to select the field which is most fertile, whereas the talent can usually be found to raise crops on the most sterile of ground—provided only that we add

enough fertilizer in the form of research appropriations. The trick, of course, is to keep the cost of the fertilizer less than the value of the crop.

How is a new product to be chosen? The history of research indicates that the odds in favor of the project are most favorable when, first, the product to be developed is riding a rising rather than a declining industrial trend, and, second, when it is started in the earlier rather than the later phases of that trend. This is very elementary, of course, and merely passes us on to the next question: How are these basic trends of industry to be recognized in time to get in at the beginning?

Only one reliable method of forecasting the future has ever been developed, and that method consists in projecting the continuing trends of the past. Also, as you know, projections—especially those of a broad fundamental nature—are the most reliable the further back they are started. Hence, any serious attempt to review the underlying trends of this country should start as far back as the Civil War, when the transition of our economy from an agricultural to an industrial type first began in earnest.

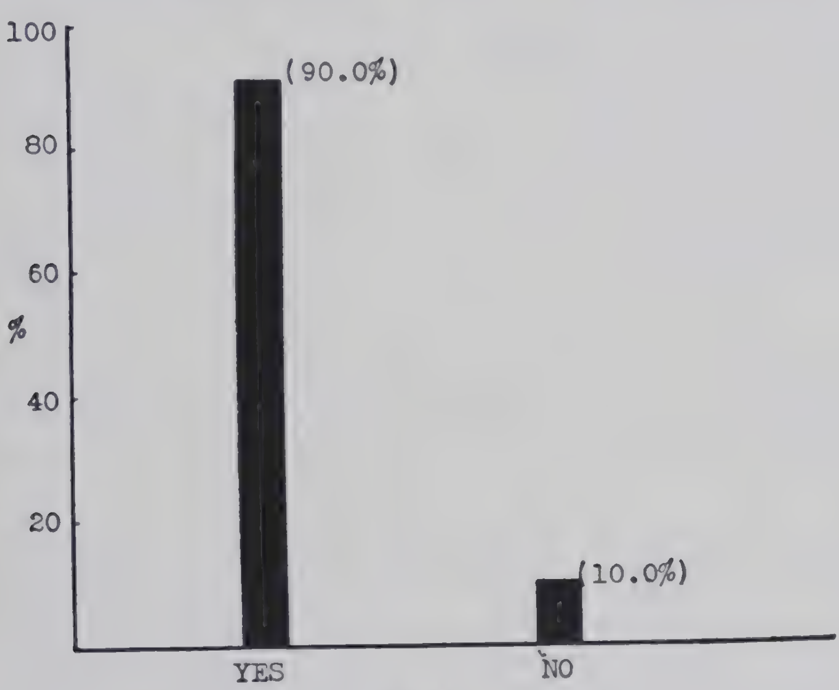

FIG. 17.

Budget

In choosing research projects there naturally is much interest in knowing if these projects are to be chosen to fit a definite financial budget. Figure 17 develops the information that such is generally not the case; rather, the project is chosen and then the budget made adequate for the solution. This should lend a great deal of encouragement to the imaginative leaders of research who are focusing their attention on the successful developments of tomorrow.

Unplanned Project Selection

Earlier in this chapter, we have indicated that 63.4 per cent of the research laboratories set a definite plan for evaluating and selecting research projects. The question naturally arises, "What do the remaining 36.6 per cent of the research laboratories do?" Are they to be thought of as an unorganized, ineffective group of laboratories? A large majority of this 36.6 per cent of laboratories, reported as not having a definite plan for choosing research projects, are usually directed—or, more aptly, inspired—by one or more stellar performers in the research field. Their performance record has been so outstanding that their personal influence has overshadowed any plan for choosing projects. One of these organizations is Eastman Kodak Company, with Dr. C. E. Mees.

The primary interest that those organizations, so fortunate in having such individuals as their generals, have is whether or not they are training young personnel to the extent that they can keep stride with the long steps made in research development by these masters of research achievement. If the answer is in the negative, surely then—as night follows day—some definite plan must be devised to insure continued success.

There is another class of research laboratory which has thousands of products listed in its catalogues. Chemical or pharmaceutical research laboratories are examples of this type. Quoting directly from one of these:

> From time to time we have attempted to formulate a definite plan by which research projects should be chosen, but the problem is so complicated that we have not evolved a satisfactory scheme. The field we try to cover is so broad that no set of rules or procedures has been developed to apply to each suggestion. Many of the items which we supply, or which we might propose to supply, are not large and any possible profits would be consumed in the making of thorough and elaborate market surveys or prolonged research development. In such cases the combined judgment of various members of the management, the Sales Manager and those engaged in directing research is relied upon.

What information does such an organization desire to secure in making these quick decisions? From this information considerable value may be derived which would be of help in the plan of choosing research projects.

The following list gives the general classification of the topics upon which this large research organization, that does not have a definite plan for choosing projects, seeks information:

Topics on Which Information is Needed Before Selecting New Projects

I. Market.
II. Use.
III. Specifications.
IV. Price.
V. Present Sources.
VI. Miscellaneous.

The specific information needed to answer these questions is obtained on the following simple forms:

I. Market.

What will be this customer's annual requirements?

.... pounds.

About how much per order? ....

Are his requirements likely to continue at this rate ....

or increase ....?

Please comment ....

....

....

....

II. Use.

For what will product be used? ....

Is the use for this product established or being developed? ....

....

Please comment on above: ....

....

Will this product replace existing product? ....

If so, what? ....

What other uses may product have? ....

How did idea originate? Literature reference ....

Patents .... Governmental department ....

Please comment: ....

....

....

....

....

III. Specifications.

What purity is required? ....

....

What impurities are objectionable? ....

....

Is any particular physical form desired? ....

....

IV. Price.

What is permissible price range? ....

V. Present Sources.

Where can product be purchased now? ....

....

VI. Miscellaneous.

What may be requirements of other companies or industries? ....

....

Please comment: ....

Will this product come under jurisdiction of the Food & Drug Administration? ....

If so, has it been accepted? ....

The information on a proposed investigation is then summarized in the following form:

Information Needed for Selecting New Projects

1. Description of Product Suggestion.
2. What Purpose Does It Serve?
3. Who Will Buy It?
4. Where Will They Buy It?
5. Is It a Bulk or Package Product?

Project No. ....

Date ....

Submitted By ....

Department ....

Date Accepted ....

Date Rejected ....

6. Are there any similar or directly competitive products on the market? If yes—Name one or more leading brands—Manufacturer's name and address—Size package—Price—and if possible submit sample.

7. If there are no similar or competitive products on the market, what evidence can you submit to show that demand or consumption will be sufficient to justify technical and market research?
8. Give any other information about the product or its possibilities which may assist the new products and development committee to properly evaluate its merit.

By direct comparison of the questions, note that the information desired for the selection of the new project in the company without a plan is almost identical in every detail to that desired by the company working under a definite, organized plan.

About the 36.6 per cent of the organizations reporting as not having a definite plan for choosing research, it must not be concluded that they do not have a definite system of securing information. It is suspected that many of the constituents of this 36.6 per cent have somewhat of an aversion to the disease known as "red tape" which occurs from intensive adherence to an over-detailed, formulated plan. Readers must not be misled into the belief that the organizations in this percentage without a plan are necessarily in a state of confusion. Quite frequently, it is thought, they will be the first to secure information in the shortest possible time. All organizations should be cognizant of the necessity of insuring themselves that they are not "over-planned," that their plans are simple and elastic, and that they secure information which is absolutely essential in selecting projects. *Any surplus information obtained serves only as a detriment to the quick execution of the formulated plan as a whole.*

If a great deal of the information obtained in planned and systematized methods of choosing research projects is similar, what are the methods of choosing research projects which are neither planned nor systematized? This can best be illustrated by dramatizing a hypothetical meeting of a committee to decide on research matters, including the choosing of projects as one item on its agenda. The time is 10:00 A.M.; five members of the committee, Messrs. A, B, C, D, and E, have arrived. The sixth member is now some fifteen minutes late. The chairman of the group is twisting nervously in his chair. The other four members have been enjoying themselves by recounting their bets and replaying the recent World Series. Finally at 10:20 Mr. F, gasping for breath, reaches the committee room.

He exclaims immediately, "Boys, I have just talked to Bill and he has sold me 500,000 units of commodity 'X' and he gave me a hot idea for a new product 'EZ.' It is something that I think will make a world beater and if we only had that we could go to town" (and so on for another five minutes).

Chairman: "Say, that does sound like something worth while; what do you think of it?"

Mr. B: "That would be swell in my department. I could say a lot of nice things about that."

Mr. C: "I think it is wonderful and I rule that it be made a research project."

Chairman: "All in favor say 'Aye'; all contrary, 'No.' Motion is carried unanimously. Mr. Secretary, will you record this new suggestion as now being made a project?"

Thus ends this meeting in so far as a choice of a new problem and project is concerned—and down the slide go the company's money and the research laboratory's valuable time and efforts on a project with a minimum chance of success. Just such a meeting and such a way of choosing new problems and projects brought the following reverberation from an outstanding research organization:

> If I may be pardoned for trying to read between the lines of your questionnaire it would appear to me that questions 11 and 12 are the type that may haunt a research organization which receives too many suggestions from other departments and has to cope to a great degree with executive pressures in choosing its work. In times past I have been a member of more than one research organization of that type and I have the utmost sympathy for the people who are confronted with that sort of problem. However, fortunately, we do not have to cope with that in this company.

Source of Projects Selected

In order to choose more wisely, notice the record of departments which have made acceptable suggestions. The following list gives the source of projects considered to be satisfactory, and recommended for intensive research. In order of their decreasing percentage:

Research	44.7
Operating	15.9
Sales	15.8
Executive	11.4
Commercial Research	4.9
Persons Outside the Company	2.5
Personnel	1.8
Advertising	0.93
Accounting	0.17

The results obtained from this statistical survey are only logical—as a physician is expected to prescribe, a research worker is expected to create. It is, therefore, natural that the greatest percentage of suggestions chosen should develop among those workers whose whole energy is devoted to discovering new facts, products, and processes. From the research laboratories of a large oil company employing some 200 personnel, there is the following bit of information:

> Our research supervisors are not cloistered in any way. They are a regular part of the company and, knowing as much about the business as they do, they are in a position to originate research projects of merit to a very great degree and probably in excess of other research organizations which are more segregated from the operating functions of their parent company.

This emphasizes the importance of the person who chooses research projects being well founded in the fundamentals of the business part of his company.

Next in order is the operating department. This is logical, as they have learned by long experience how to make the products or to conduct the processes, and from them many projects worthy of final selection for research may be expected.

Sales is the next most logical department for the origin of acceptable suggestions. This is particularly true because it is the representatives from this department who have contact with the users and consumers of the product and the processes involved. According to one large manufacturer of pharmaceuticals and chemicals: "As I indicated, a major portion of our projects originate in the sales field, not necessarily by the salesmen or the sales department but perhaps by some technical man through contact with our customers. These contacts may reveal new products or processes which are needed." This is logical because the pharmaceutical, medicinal, and chemical field, in a majority of instances, has scientifically trained salesmen who in turn call on pharmacists, doctors, chemists, engineers, etc. It is only natural in these fields that a higher percentage of projects finally chosen should originate in the sales field.

The dominant role of the sales department as a source of research projects in the pharmaceutical field is shown by one such laboratory reporting that the source of its projects was as follows: Executive 5.0 per cent, Sales 60 per cent, Legal 5 per cent, Operating 20 per cent, Research 10 per cent. This is a markedly different trend from that shown by the data given above. The fact that some 60 per cent of these projects chosen were obtained by technical men calling on highly trained individuals in the professional field strongly suggests that the percentage of chosen projects arising from the sales departments in general might be materially increased by employing some highly trained technical men in this department.

Departmental Participation in Selection of Projects

Before proceeding further with this discussion the question should be asked, "Who chooses research projects?" The answers to this question are exceedingly interesting.

> 1. From a research laboratory of high repute employing 25 personnel, comes the following: "If you are talking about research, I can't imagine there is anyone who can choose the problem except the researcher himself. Research is a personal endeavor. It is an insatiable curiosity and a desire for knowledge which is prominent in some people and not in others. Perry, Alexander the Great, Galileo, Darwin, Einstein, Madame Curie, and others have all added to the book of knowledge, even at the risk of their lives, of excommunication from the church, of ridicule, and of starvation conditions. No one can create a researcher or choose a research problem for a true research man. You have heard Dr. Mees' history of his own experience. Mine is the same. No one has ever told me what he wanted done and I suspect that is pretty much of your own experience."
>
> 2. From a most outstanding laboratory employing some 3000 personnel: "The —— —— laboratories as a unit of the —— system has a broad responsibility for undertaking and carrying through those lines of research which, in their own opinion, are beneficial to the organization. This research unit conducts largely partially applied research work."
>
> 3. From an outstanding research laboratory in the glass industry, employing approximately 200 technicians: "Our research projects are selected by the research director, suggestions being sought from other groups such as executive, manufacturing, sales, and market analysis."
>
> 4. From Dr. C. E. Mees: "No other departments of the organization participate in choosing research projects, but as indicated above, consideration is given to the request of the manufacturing departments whenever they suggest that certain types of work are of importance to them. To a lesser extent the sales department also asks for assistance and suggests problems, but work originating from this source does not constitute 5 per cent of the total work of the laboratory. Approximately 20 per cent of the laboratory activities are concerning problems that are suggested by the operating department and which are recognized by the laboratory personnel as being of importance to the operating departments."
>
> 5. From Mr. P. W. Pillsbury, President of Pillsbury Mills, Inc.: "In other words, it is not up to management or the board to direct research

outside of laying down some fundamental policies but it is up to research to bring up projects along the lines the company is best fitted to proceed on, and get the blessing and encouragement from management."

6. From a research department of international repute which employs over 500 persons: "In our setup, I think that it is fair to state that essentially all the research projects originate within the research laboratories and the decision to do work upon them is a research function. This does not mean that we fail to take advice from the operating and manufacturing units. As one means for assuring a proper program, we have an Advisory Board which is made up of the principal technical executives of each of the several branches of ——. This Advisory Board meets with us several times each year—not only for a review of our program but also that of the technical requirements of the several branches represented on the Board. This and several other procedures for maintaining contacts and co-ordination, naturally, lead us in the direction of a useful and logical program of research for ——. In the last analysis, however, this Advisory Board and the other means to which I have referred are advisory in nature and the decisions are made, both as to work program and the priority of projects, within the research group."

In direct contrast to the above-mentioned instances where the projects are chosen exclusively by the research department, the answers to the questionnaire revealed that in approximately 8.5 per cent of the organizations, other departments choose projects for research without previously conferring with the research department.

In approximately 87.8 per cent of the cases the research projects were not chosen exclusively by the research personnel but in close co-operation with certain departments of the organization. In the remaining 12.2 per cent of the cases the projects were chosen exclusively by the research personnel.

The answers to the question, "If the research projects are not chosen exclusively by the research personnel, to what relative percentage does each department of your organization participate in choosing these projects?" gave the following data:

Average Percentage participation of Various Departments in Selecting Research Projects:

Research	48.5 %
Operating	18.2
Sales	16.4
Executive	13.5
Legal	1.2
Advertising	1.1
Accounting	0.17
Traffic	0.12

In laboratories where this co-operation does not exist to its fullest extent, it is frequently found that a project is chosen and actually worked on, sometimes to completion, without the knowledge of other departments. Then, when the final report is presented, some department points out a good and valid reason why this project which was chosen and completed, cannot function. This has happened many times, and the time required to tell why the results of the project were not usable was but a very few minutes.

One large research organization from the medicinal field has the following to say:

> I should point out that it is not mandatory that contemplated research programs go to the special committee. Its primary function is to save the research group the hours of work that might be spent in attempting to develop a product that would be unacceptable to sales or to top management even if the research were eminently successful.

One research organization describes the method which has helped them to overcome this particular difficulty as follows:

> This type of close co-operation between sales, operating, and research has worked out very well in our company. Perhaps the main reason it has worked out so very well is that operating and sales are given a share in the responsibility of the direction of research. Products and processes that are developed are thus assured of a good reception from both the sales and the operating departments.

Another very successful research organization says:

> One of the greatest destroyers of research organization morale is to complete a worthwhile project, obtain favorable results and then find that the results are not used . . . either because the market is not ready or for one of many other reasons. In our organization, we devote considerable attention to this situation to make sure that adequate consideration is given to all the results of our research.

Another laboratory, which is considered to be one of the top-ranking research laboratories in this country, has the following to say:

> We [the research department] have always maintained that we should have the final vote on any projects submitted for research. In making decision, however, we would attempt to get full facts from the commercial department, operating department, or sales department so that we could weigh its importance. We would then consider another factor which might cause us to put our efforts on a less important problem.
>
> This factor is an analysis of the probability of returns. For example, if one of our men had a good idea on the solution of a given problem we might decide to work on that one in preference to one with

> two or three times the potentialities providing no one had a good lead how to solve the more important problem.
>
> In general, the above considerations apply to projects thought up in our own research laboratory, and we try to make no difference in our consideration whether an idea originates with our men or in one of the other departments. Obviously, this is not always easy to do since it is human nature to give preference to your own ideas.
>
> The success of the above approach rests entirely with the amount of confidence the research organization has built up with the other departments. We are fortunate in having a very close and cordial working arrangement with other divisions that are closer to us than others. It might be said, however, that while we maintain the right to have the final vote on which projects are to receive our attention, we would not be so discourteous as to refuse a project without giving our complete reasons. Furthermore, we would make every attempt to convince the party that our reason was sound. During such conferences it would develop that we would either convince them or be convinced ourselves, and this is the secret of any successful program of applied research.

It is thus quite evident that co-operation between these departments is essential. One of the contributors, a well-known research organization with a personnel of approximately 110, has aptly summarized what is hoped to be accomplished by this co-operative endeavor:

> 1. To recognize that good ideas are likely to come from any department in the organization.
> 2. To attempt to channel these ideas through a committee composed of business and research personnel which is called the Project Committee.
> 3. To set up for each management division a complete research program, bearing in mind which jobs should take priority in terms of their importance to the corporation and how much money this particular manufacturing division can afford to invest in the program.

What should the selected projects include? This is an extremely important question. In the case of a medium-sized chemical company it has been answered by Dr. C. L. Gabriel [2] as follows:

> The subjects for research must be selected with extreme care and should include:
>
> Improvement in processes
> Utilization of by-products
> New chemicals which should be made in order to round out lines of products sold to various industries
> New developments which may possibly have nothing at all to do with the company's immediate business.
>
> New fields must be studied from a sales standpoint before research work is initiated too deeply.

Chronological Order of Procedures in Selecting Projects for Research

In selecting research projects the following steps should occur at some time.

1. Legal investigation.
2. Sales survey to determine demand for the product.
3. Executive investigation to determine company's ability to manufacture, distribute, and sell the product.
4. Exploratory research investigation to determine possibilities of developing the project or solving the problem at hand.
5. Intensive research investigation, terminating with development or solution of the problem.
6. Pilot plant operation.
7. Intensive patent survey.
8. Literature survey.

The relation between the various percentage levels and the chronological order at which each of these procedures has taken place in the laboratories submitting data is shown in Figures 18 to 24.

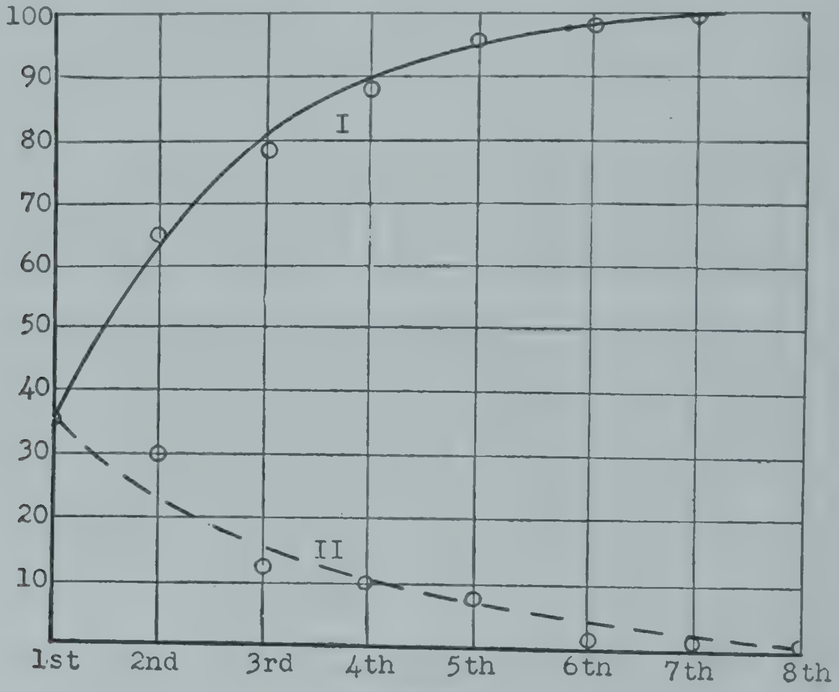

FIG. 18.

Figure 18 shows that 35 per cent of the research laboratories make their literature survey in the first step, as shown by the dotted line. The solid line at the top indicates that 65 per cent of the literature surveys are completed by the second step and some 78 per cent by the third step. It is quite evident that literature surveys are one of the first things that must be thoroughly undertaken before attempting to decide or choose a research project. One research director expresses the importance of this as follows:

> Always, the research is preceded by a thorough search of the literature and it is usual for this literature research to continue throughout the problem. In fact, workers are expected to keep thoroughly read in their general fields at all times and time is freely granted to them for that purpose. It is one of the most essential, in fact, indispensable privileges of the research worker.

Figure 19 shows that exploratory research investigation is completed in the first step in approximately 37 per cent of the cases.

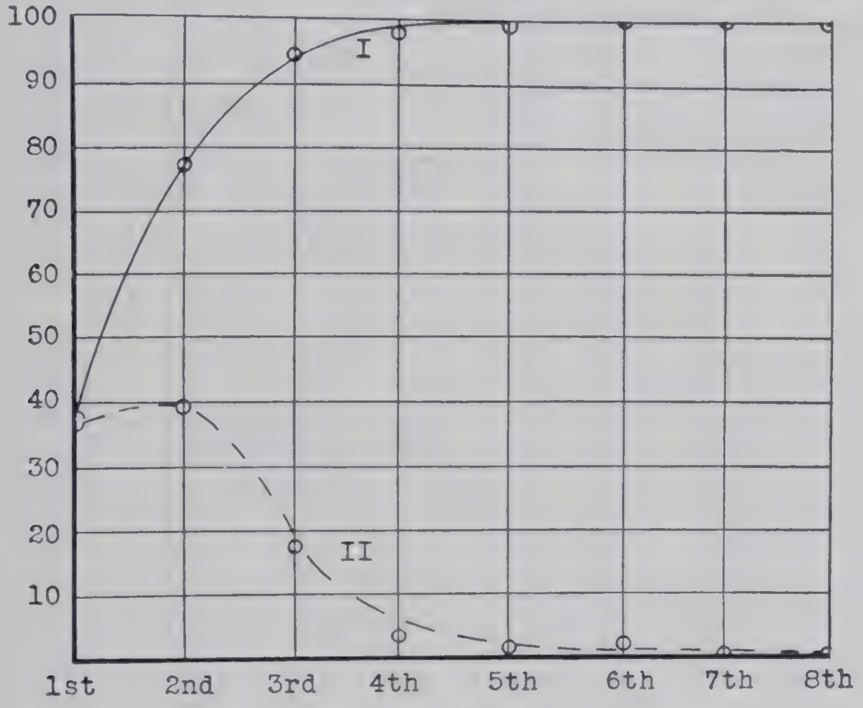

FIG. 19.

Exploratory research reaches its maximum activity during the second step where approximately 77 per cent of the research laboratories reporting have completed or started their exploratory research.

It is thus quite evident that exploratory research rivals literature survey as an important primary step before a decision can be reached in regard to the choice of a research project. One nationally known research laboratory in its scheme of evaluation of research projects under the section headed "Preliminary Appraisal" has the following to say: "If the recommendation is accepted, brief exploratory evaluations are carried out either in the library or laboratory, or both, to determine technical feasibility of the idea. This work is limited in scope."

This laboratory has a simple pair of forms which it uses to point up the results of exploratory research for consideration of further work.

RECOMMENDATION FOR RESEARCH

The Undersigned Herewith Recommends the Following Project for Investigation

Product or Process

Object to be Sought in the Investigation

Possible Methods of Attack

Reasons Why of Interest

Signed ....

NOTICE OF DECISION

On Recommendation for Research Investigation

TO .... Date ....

The Recommendation for Research No. .... Submitted by You Under Date of .... Has Been Investigated, and the Following Decision Arrived At by the Executives of the Company.

Product or Process

Object to be Sought in the Investigation

Decision (state whether accepted for exploratory or project status: why favorable action is withheld at this time: or the reason the recommendation will not be carried out)

Figure 20 is a frequency graph for sales survey. Here it is found that the sales surveys are at their maximum intensity at the very first step. The percentage, however, is only approximately 32 per cent. From this point they materially decline and the rate is practically constant between the third and the fifth steps. This is indicative of the fact that the character of some of the products or processes resulting from research is very well known and an early sales survey is often undertaken as one of the first steps. The results of research, however, are quite frequently of an unknown character, and no sales

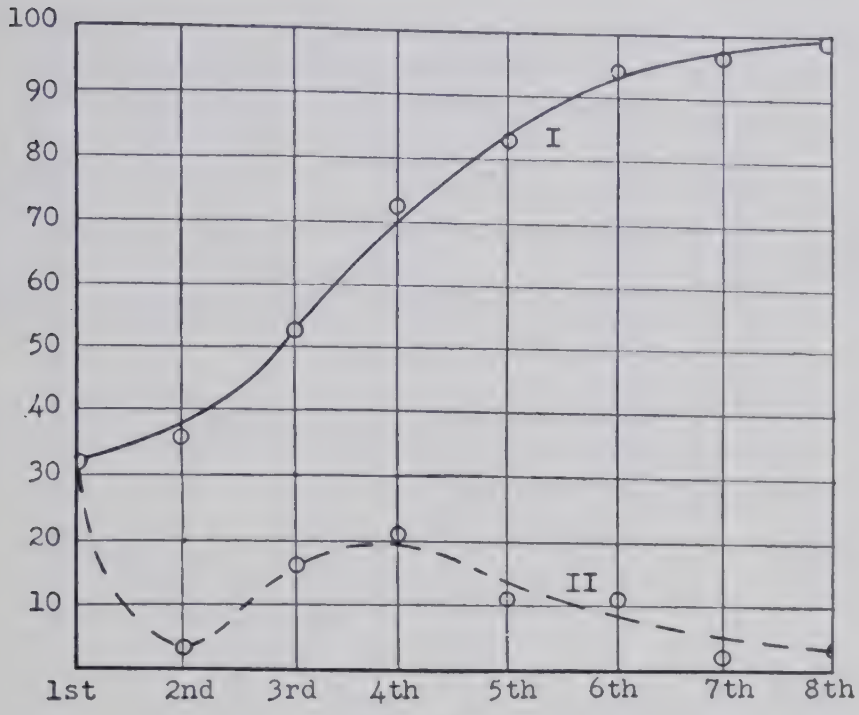
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FIG. 20.

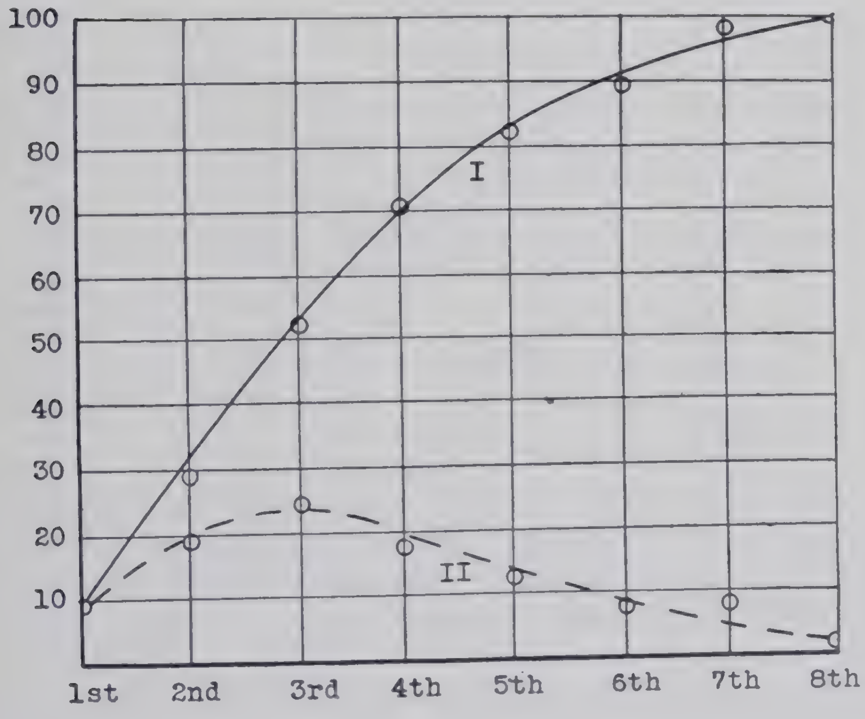
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FIG. 21.

survey is possible until the specific properties and qualities of the product or processes have been established. It is probably for this reason that the sales survey rate remains somewhat constant between the third and sixth steps.

Figure 21 is a frequency graph for the executive investigation. Here the maximum rate is obtained in the third step. At the end of the third step some 52 per cent have been started, while at the end of the fourth step some 70 per cent have been started or completed.

This executive investigation is largely concerned with the particular company's ability to manufacture, distribute, sell, and finance the specific product or processes.

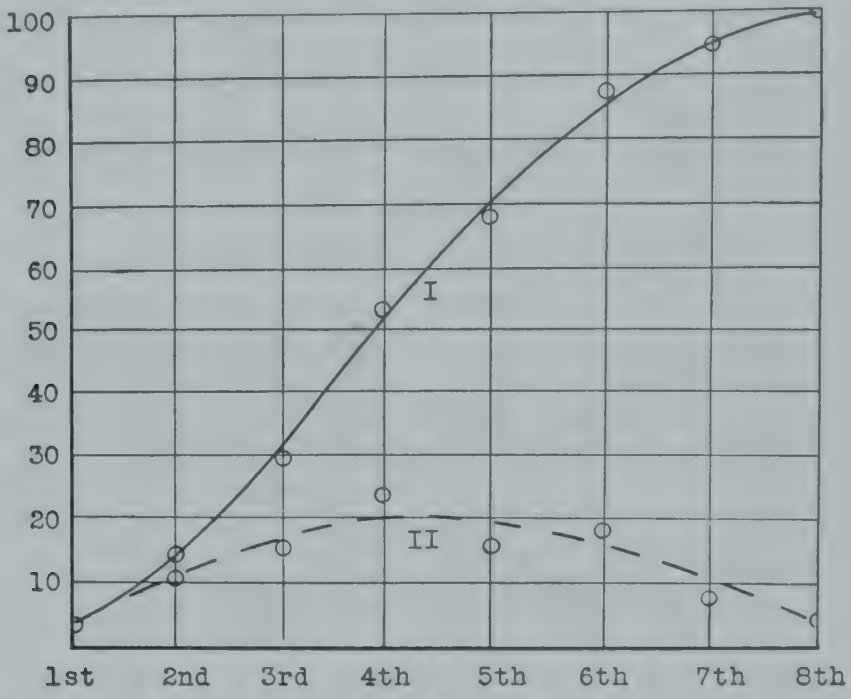

Fig. 22.

Figure 22 shows the frequency curve for intensive patent surveys. A maximum rate is obtained in the fourth step where at least 53 per cent of the patent surveys have been started. At the fifth step some 69 per cent of the patent surveys are either completed or in active state.

In Figure 23 the frequency curve shows the status of pilot plant activities. As might be expected, little activity in pilot plant opera-

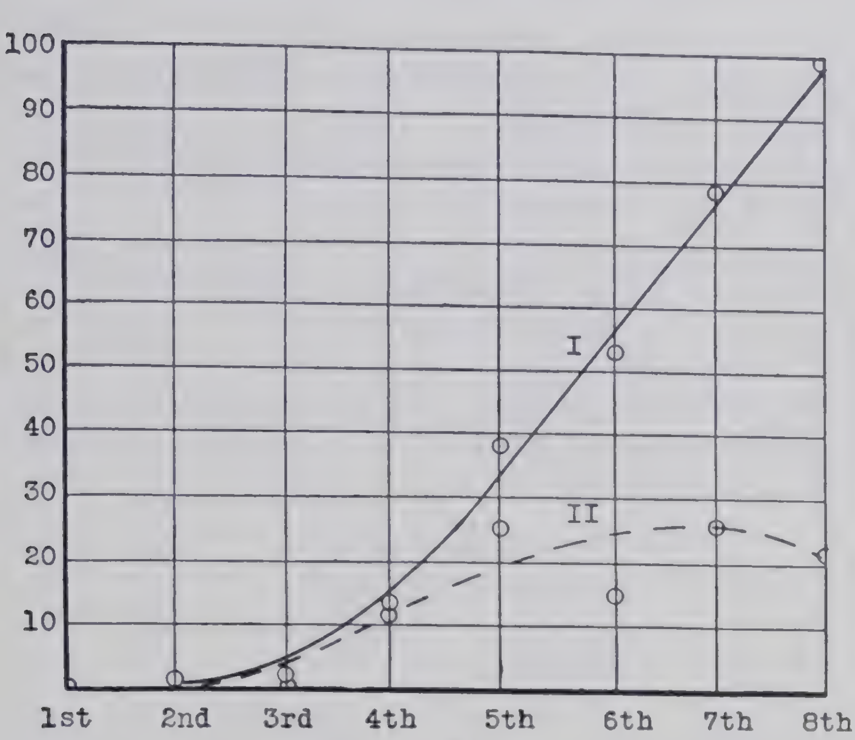
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FIG. 23.

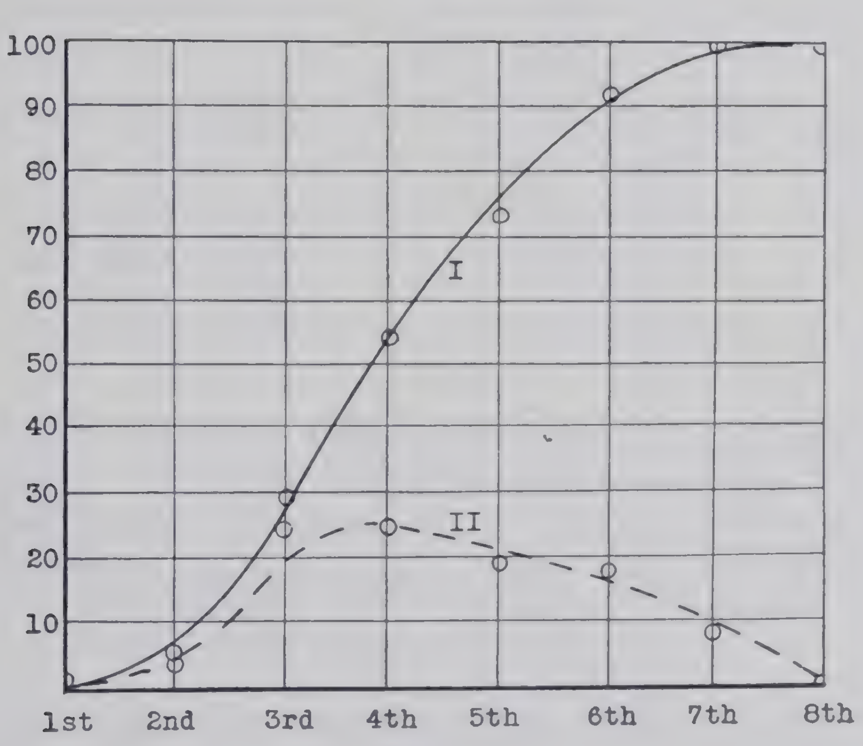
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FIG. 24.

tion is evident before the fourth or fifth steps. The maximum rate of activity is at the seventh step where some 78 per cent of the pilot plant operations are in progress.

Perhaps the most interesting curve of all is the frequency curve (Figure 24) for the beginning of intensive research investigations. Here, the rate of occurrence is almost constant between the third and sixth steps. It is very significant that at the beginning of the fifth step some 73 per cent of the intensive research investigations are in progress. This implies that there are four definite steps which should be taken before intensive research is under way. Interpreting from these frequency graphs it would be judged that the order in which these steps should occur are as follows:

1. Exploratory research.
2. Literature survey.
3. Executive investigation.
4. Sales survey.

As a matter of fact, the fourth step, sales survey, could well be included as a part of the third step, namely, executive investigation. In a written communication Dr. Mees has also included sales survey under executive investigation.

ORDER OF PROCEDURES IN SELECTING PROJECTS FOR RESEARCH

Step No.	*Frequency Curve*	*Dr. Mees*
1	Exploratory Research	Literature Survey
2	Literature Survey	Exploratory Research
3	Executive Investigation Including Sales Survey	Executive Investigation Including Sales Survey
4	Intensive Research	Intensive Research

Fig. 25.

Figure 25 is of a great deal of interest in that it shows the relative order of these steps as compared to Dr. Mees' rating. The agreement arrived at is excellent. Other contributors have confirmed it with their ratings, but our space does not permit a recording of their results. These relative orders seem fairly well established. It must, however, be remembered that no absolute policy can be strictly adhered to, and under certain specific conditions, as one of the research directors advises, frequently many of these steps may be going on concurrently. It is quite conceivable that steps one, two, and three, in case of emergency, may be in progress simultaneously. For this reason the sum of the ordinates of Figures 18 to 24, for a given step, may total more than 100 per cent.

Another large research organization makes the following suggestion:

> As regards chronological status, we find it advantageous to carry on several activities at the same time and I have so indicated in the questionnaire. I suppose that if one were to formalize research activity without regard to date of completion, a strictly chronological order for all the items you have mentioned could be determined but we find that it is necessary for us to telescope our program in many instances, it being obviously to our advantage to do so in order to reach the market with a specific product.

Many persons have referred to research as a gamble. It is to be hoped that these persons also remember that a professional gambling house never loses. In the long run it always wins. If steps one to three inclusive are thoroughly followed before choosing a problem for intensive research, an organization will place itself in the winning column a greater percentage of the time.

The specific subject of choosing research projects is only one unit of the complete research program. It is for this reason that this chapter has omitted presenting the complete organizational plan of research. The sales surveys should be completed, the literature investigated, and an expression of opinion regarding the chances of accomplishment by the research department should be thoroughly recorded. These facts should then be presented to the organization as a whole and the decision made as to the course of procedure. Certainly, if, for a given project, the research department advises, with well-given and well-founded reasons, that the chances of accomplishment by its specific personnel are very small, it would be somewhat unwise for an organization to fill the schedule with such projects. It would be far more advisable to consult other research organizations and, if any of them should think the given project is highly susceptible of solution, it would be well to "farm out" that particular project to an organization outside of the company.

A very outstanding research organization has the following to say:

> When one in industry does research of a scientific nature, it is only natural that the work done be in keeping with the qualifications of the members of the technical staff. This is more particularly true when

> the projects originate within the research organization. It is necessary, however, at times to enter into new fields where the skills or facilities needed are not available. In such cases, we add to our staff, both by employment and by the establishment of consulting arrangements, the men needed to undertake the new work.

None of this latter refers to pure or applied research, where the definite outcome cannot be seen, but more particularly to those projects upon which realization should reasonably be expected in a term of six months to a year or two years.

In presenting this survey, the author has impartially selected those quotations from the replies of 121 research organizations which seemed to be outstanding and which would be of assistance in making a better choice of research projects. Such selection is one of the first fundamental steps in embarking upon a well founded research program. If the projects are ill chosen, poorly timed, and inadequately fitted to the company's need, the ship that carries them, as well as its crew, will ultimately meet with disaster.

Summary

1. A majority (63.4 per cent) of the organizations have a definite plan for selecting research projects. Very few of these organizations adhere to their plan 100 per cent of the time. This should be considered a mark of sound judgment, as sufficient freedom must be allowed to permit functioning in various types of emergencies.

2. Research projects on the average were distributed as follows:

Short term	29.4%
Long term	36.7%
Continuous	28.8%
Miscellaneous	7.9%

The chances of success seem to be about equal in the solutions of long-term and short-term projects.

3. The qualifications of the specialized personnel of the department were taken into consideration in selecting research projects by 44.1 per cent of the laboratories. However, 83.9 per cent of the organizations indicated that they choose a project, then later attempt to acquire personnel suitable for the specific project, if they are not already available.

4. Nearly all of the organizations recognize the importance of sustaining individual initiative and morale. Most (57.5 per cent) do

so by choosing projects that have a high probability of solution, and distributing them to personnel concurrently engaged in the solution of long-time projects. Others have indicated that they maintain the morale of the research worker by pointing out to men engaged in long-time research the fact that it may be some time before their results can be put on an operating basis.

5. The research project must be timely. The odds in favor of the project are most favorable when the product to be developed is riding a rising rather than a declining industrial trend.

6. Nearly all (90 per cent) of the organizations indicated that the research budget is flexible and is made adequate for the solution of a project after selection.

7. A research project should do one or more of the following:

a. Reduce cost of production.
b. Reduce operating cost to the user.
c. Increase the utility of the product.
d. Increase its sales appeal.
e. Produce new business.
f. Determine technical information contributory to some other project.

8. On the average, projects chosen for research originate as follows:

a. 44.7% from the research department.
b. 15.9% from the operating department.
c. 15.8% from the sales department.
d. 11.4% from the executive branch.
e. Varying smaller percentages from other departments.

In some organizations employing technical men in the sales field, a much larger percentage of acceptable suggestions was obtained from this department. This percentage ran as high as 60 per cent in one such organization in the pharmaceutical industry.

9. The average percentage participation of various departments in selecting research projects was as follows:

a. Research	48.5%
b. Operating	18.2%
c. Sales	16.4%
d. Executive	13.5%
e. Legal	1.2%
f. Advertising	1.1%
g. Accounting	0.17%
h. Traffic	0.12%

10. Very few (8.5 per cent) of the organizations indicated that other departments choose projects for research without previously conferring with the research department. Also in the minority (12.2 per cent) were laboratories where projects were chosen exclusively by the research personnel.

11. A definite chronological order of procedure for examining projects suggested for research is indicated. This procedure is as follows:

First—Exploratory research.
Second—Literature survey.
Third—Executive investigation including sales survey.
Fourth—Intensive research.

12. The 36.6 per cent of the research laboratories which indicated that they had no plan for selecting research projects seem to fall into two groups. The first of these consists of those organizations fortunate in having as their directors men so outstanding that their personal influence has overshadowed any formal plan for choosing projects. In the second group lie industries of the chemical, pharmaceutical, and similar types where the field is so broad that no set rules of procedure can be developed.

Recommendations

These recommendations are made with full realization that there will be some exceptions to their application by all research organizations. They are general in character and suitable variations should be introduced to suit specific organizations. Research, by its very nature, cannot be tailored to any set pattern, and methods for selecting research projects will naturally present different problems to different organizations.

1. A clear-cut statement of company policy by top management with respect to the hopes and aims which it desires to realize from the research department, in the form of products, processes, or fundamental research, is extremely important in expediting the choice of projects for future selection. Without a clear-cut policy statement by top executives, the selection of research projects starts on a weak foundation.

2. Any plan for choosing research projects must be sufficiently elastic so that it will take care of any emergencies which may arise. This plan must not be so detailed that it becomes a "red-tape" pro-

cedure, and yet it must secure essential information. Superfluous information must be scrupulously avoided as it serves only as a detriment to the speedy selection of projects.

3. In basic or fundamental research, the general broad field of activity can be pointed out. The researchers in these fundamental fields should be left free to choose detailed projects and their method of pursuit.

4. The consideration of potential research projects bears heavy responsibility. Far too many projects are chosen by research supervisors and executives without adequate study and without compilation of sufficient data, following the way of least resistance. These hastily chosen projects are the ones which too frequently result in unsatisfactory returns to the company. In order to remedy this condition it is recommended that certain preliminary investigations be made fundamental prerequisites for the securing of essential data upon which to base the choice. The chronological order for these prerequisite investigations is as follows:

First—Exploratory research.
Second—Literature survey.
Third—Executive investigation, including sales survey.

These may be changed in sequence or, in cases of emergency, conducted simultaneously. It is recommended, however, that steps one and two precede the third step. It is obvious, of course, that if any of the early steps render the project impossible or undesirable, the succeeding steps are unnecessary.

5. The projects chosen should be thoroughly investigated to determine whether or not they coincide with the present or future activities of the organization.

6. It is definitely recommended that short-term, miscellaneous, and exploratory research be left to the jurisdiction of the research department. Here is the opportunity for the development of individual initiative. Exploratory research offers the chance for assembling data and information on proposed projects or processes for assistance in their final selection.

7. The execution of exploratory research, literature survey, and executive investigation pre-empts close co-operation between the research, sales, operating, and executive departments. This liaison should be intensified where there is resistance to the acceptance of the fruitful research results from chosen research projects.

8. Too frequently the research personnel are branded as being too technical and impractical. To obtain the greatest efficiency in the selection of research projects and their pursuit in the research laboratory, it is recommended that the key men of research organizations be given the opportunity to become well grounded in their company's practical business operations.

9. The survey shows that in certain industries wherein the salesmen are technically trained, a higher percentage of chosen projects comes from the sales department. It is recommended that careful consideration be given to the addition of technically trained men in those cases where the sales department contributes a low percentage of the chosen projects. Such an addition may well be instrumental in increasing this percentage, since the sales personnel are in position to meet the consumers or users of the products or processes.

10. It is recommended that if a suggestion is rejected the reasons for such action be clearly stated. This information should then be given to the individuals from whom the suggestion originated. They in turn, if not convinced by these reasons, should be given freedom of rebuttal. It frequently happens that information so offered is of such value as to alter or modify the former decision.

11. It is recommended that the person or committee responsible for choosing research projects recognize that a good suggestion may originate with any individual, committee, or department, and that all suggestions should be thoroughly evaluated before a choice is made. It is further recommended that these suggestions be accompanied with some idea of their potentialities and means of achievement. These ideas may be in an extremely nebulous state. They are, however, of definite assistance in exercising a choice. It is not essential that they be given in detail, as such development in itself is the function of research. The insistence upon some means of achievement to accompany the proposed project is productive of good suggestions and minimizes "rainbow thinking."

12. It is recommended that a record be kept of the termination of all research projects, indicating whether or not they were satisfactorily completed. This log should include a short statement of why they were successful or unsuccessful. Such an accumulation of information will be of assistance in two specific ways:

a. In choosing future research projects.
b. In determining when to terminate a chosen research project.

Acknowledgements

The material of the foregoing chapter was originally prepared for a seminar on Management of Research given by the Armour Research Foundation at the Illinois Institute of Technology. The Foundation is to be complimented on organizing and supporting this course, as it has proved to be most useful in bringing systematic consideration to bear on the problems of research management.

The author wishes to acknowledge the valuble assistance of Dr. F. L. Gunderson, Research and Product Development Vice-President, Pillsbury Mills, Inc., and of Messrs. R. O. Brown, H. W. Lincoln, and K. A. Gilles, of the research staff, in the preparation of the foregoing material.

The author also wishes to extend his thanks and gratitude to the directors and personnel of the many research organizations who have generously contributed both time and concrete data. Many of them have requested that their identity be kept confidential and it is for this reason that they are not specifically named.

APPENDIX

Questionnaire on the Selection of Research Projects

1. Do you have a definite plan for choosing research projects? Yes........ No........

   a. Indicate percentage of cases in which this plan is adhered to in choosing research projects. ....

   b. What projects as to type or source are not chosen under ....
   your routine plan? ....
   ....
   ....

2. Are the research projects chosen exclusively by the research personnel? (The term "Research Personnel" implies persons or institutions such as universities and other organizations devoted exclusively to research.) Yes........ No........

3. If the research projects are not chosen exclusively by the research personnel, please indicate the relative percentage that departments of your organization participate in choosing research projects:

   a. Executive. ....

   b. Legal ....

   c. Accounting. ....

d. Sales. ....

e. Personnel. ....

f. Operating. ....

g. Advertising. ....

h. Traffic. ....

i. Research. ....

4. Are research projects in your organization chosen to fit the specialized personnel of your Research Department? Yes..... No.....

5. Are research projects chosen to develop a specific product or solve an existing problem and qualified personnel later acquired for the project? Yes......... No.........

6. Mark in chronological order the following procedures as they occur:

.... Legal investigation.

.... Sales survey to determine demand for product.

.... Executive investigation to determine company's ability to manufacture, distribute, and sell product developed.

.... Exploratory research investigation to determine possibilities of developing the project or solving the problem at hand.

.... Intensive research investigation terminating with development or solution of the problem.

.... Pilot plant operation.

.... Intensive patent survey.

.... Literature survey.

7. Indicate what proportion (percentage) of your projects are distributed as classified below:

a. Short-term projects of approximately 6 mos. ....

b. Long-term projects extending over several years. ....

c. Continuous projects such as method, process, or product improvement. ....

d. Projects which result in no definite return to the company such as preparation of magazine articles, co-operative research with public, educational, and experimental institutions. ....

8. To sustain individual initiative and morale, are projects chosen which have great possibility of solution and distributed to personnel concurrently engaged in the solution of long-time projects? Yes........ No........

9. If a survey (sales, legal, consumer requirement, etc.) shows certain processes, products, or projects to be very desirable, is such made a problem immediately without consulting the Research Department as to the probability of its solution? Yes........ No........

10. Are research projects chosen—

    a. To fit a certain definite financial budget? Yes........ No........

    b. And budget made adequate for their solution? Yes........ No........

11. Please supply statistics which indicate the percentage of the projects below which result in satisfactory solution:

    a. Long-term projects. ....

    b. Short-term projects. ....

12. Of the projects chosen, what percentage of them originate from—

    a. Sales. ....

    b. Legal. ....

    c. Executive. ....

    d. Operating. ....

    e. Advertising. ....

    f. Accounting. ....

    g. Personnel. ....

    h. Commercial Research. ....

    i. Persons not connected in any capacity with your organization. ....

    j. Research. ....

13. Of the projects finally resulting in satisfactory solution, what percentage of them originated from—

    a. Sales. ....

    b. Legal. ....

    c. Executive. ....

    d. Operating. ....

    e. Advertising. ....

f. Accounting. ....

g. Personnel. ....

h. Commercial Research. ....

i. Persons not connected in any capacity with your organization. ....

j. Research. ....

14. Is a bonus given to individuals outside of the Research Department for project suggestions that are finally accepted for research investigation? Yes ...... No

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CHAPTER VIII

The Research Budget[13, 14, 22, 27][*]

Why Budget?

The preparation of a budget for the research department is advantageous as an aid in planning the activities of the department, in providing assistance to the executives of the company in setting up the company budget[2] and planning company activities, and finally as an assurance of continuity of the research effort.

The preparation of the departmental budget, if properly performed, entails the critical examination of recent and current rates of expenditure as well as the projection of them with suitable modifications for a reasonable period into the future. The examination of past and current expenditures may well bring to light over-expenditures in some directions and under-expenditures in others, which may be corrected with resulting benefits to the work of the department.

Estimates of future expenditures must be based, among other things, on plans for expansion or curtailment of departmental personnel, revisions in wage scale, provisions for merit increases and promotions, increased emphasis and expenditures on existing lines of endeavor, and also the initiation of new programs. Decisions to increase or decrease the rate of expenditure for items other than salaries or wages must be taken into account, as for example, for publications purchased, outside services purchased, travel expense to be permitted in attending meetings, etc.

Submission of a carefully planned budget to company management will help markedly in building their confidence in the business

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This chapter by J. M. McIlvain, Administrative Supervisor, Research and Development Department, Atlantic Refining Co.

[*] References cited have been selected as helpful supplementary reading and not necessarily as authority for, or agreement with, statements in the text.

capabilities of the research department. It will provide them with a sound basis for allocation of funds to the research department and will help to assure a continuity of their support by providing evidence of the necessity for long-range planning of research work. The importance of continuity of research effort was recognized even in the depression by many companies [16, 24] and has been emphasized repeatedly since.[9, 23]

When Budget? [6, 20]

The budget should be prepared for a period which is long enough to provide real continuity to the research efforts and yet not so long that the estimates become merely guesses. Depending upon individual circumstances, it may be preferable to budget on a monthly, quarterly, or annual basis. It would appear that a monthly budget would be of too short a duration to provide adequately for long range planning. On the other hand, a budget prepared annually in many cases will not be flexible enough to be valid for the latter part of the period. In fact it may interfere with proper operations by fostering an end-of-the-year, temporary interest in costs and budgets and a relaxation in the early part of the year to a state of inadequate attention to such matters. A budget prepared quarterly but looking forward for a period of twelve months, broken down to show budget by months for the first quarter and by quarters for the remainder of the period, has the advantages of providing details on expenditures in immediate prospect and at the same time a more over-all picture of those for a longer period.

How Budget? [11]

Accounting practice as well as the nature of the expenditure makes it customary to prepare separate budgets for those expenditures which on the one hand will result in capitalizable items, and on the other hand will be charged off currently as items of expense. The nature of research activities is such as to result in annual expenditures for items of expense usually many times greater than those for capitalizable items. This being the case, and also because proposed expenditures for capitalizable items in most companies will be subject to individual review by company management, the capital budget may be prepared much more simply than that for expense items.

The Capital Budget

This may be prepared under two general headings, the first, *capital requirements,* and the second, *capital contingencies.* Under the heading capital requirements will be listed a brief description and the estimated cost of each item which the research department can foresee as necessary during the budget period. This provides management with the information needed from the research department to plan for other than continuing expenditures. In many compa-

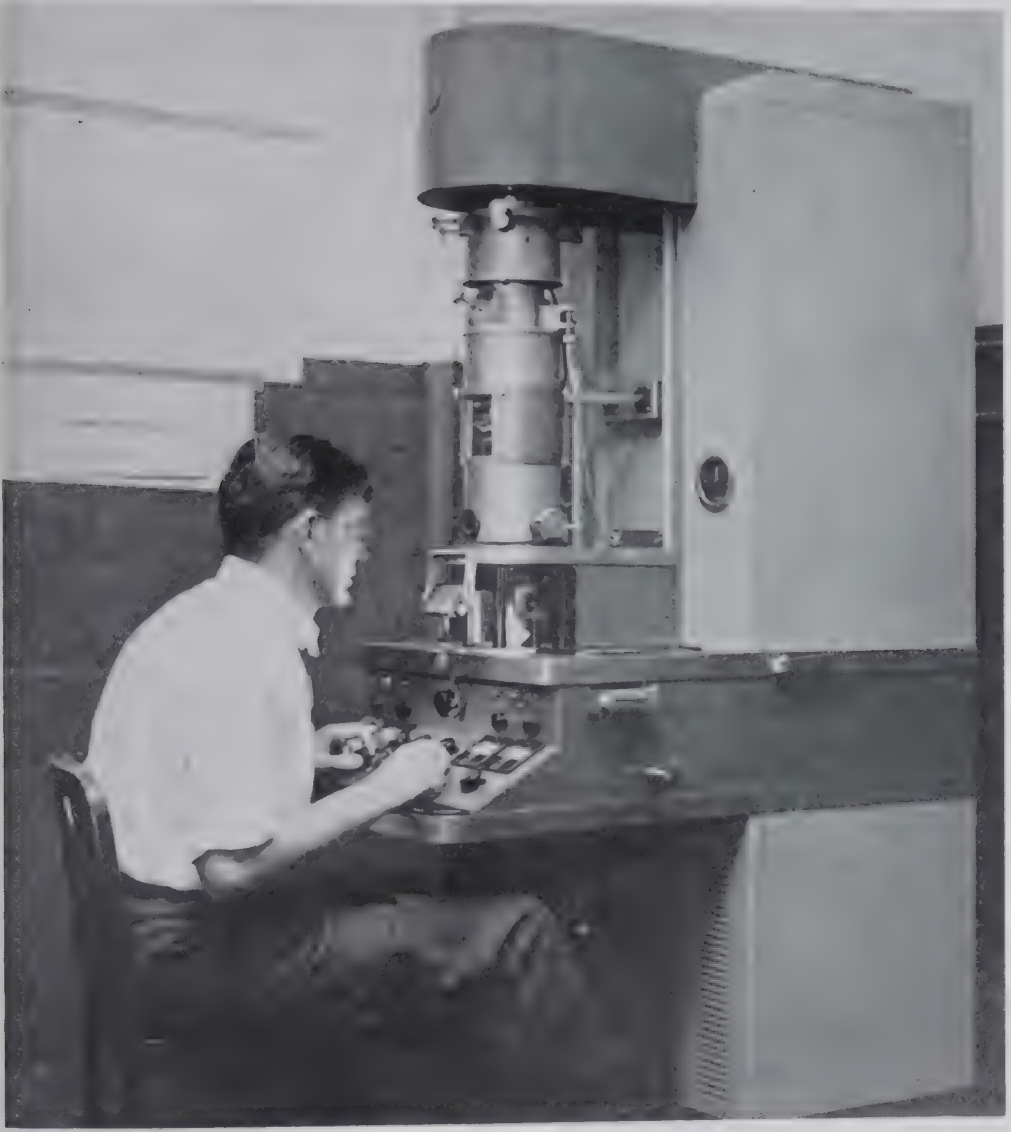

PHOTO. 14. An electron microscope. Capital expenditure for up-to-date apparatus is a necessary part of budget consideration. *(Courtesy of the United Shoe Machinery Corporation.)*

nies the research department's requirements will be minor in comparison with those of other departments where substantially larger investments in equipment, buildings, etc., are needed. An exception would occur in a budget period in which the research department anticipated a major capital expenditure such as one for a new building. Under the heading of capital contingencies would be listed a brief description and estimated cost of those capitalizable items which the department considers might become necessary, depending upon the outcome of work in progress or the completion of plans in development. Ordinarily these items would concentrate in the latter part of the budget period and some of them would be transferred to capital requirements in the preparation of subsequent budgets.

The Expense Budget

The experience of many of those engaged in research administration indicates that the major item of research expense is that of salaries and wages,[4] which generally amount to two-thirds to three-quarters of the total expense. For budgeting purposes, therefore, it becomes necessary to examine in considerable detail the changes in the rate of expenditure for these items which may be expected during the budget period. This includes the effects of separations and additions which may be expected as the result of usual turnover, anticipated unusual additions or reductions in the staff, provision for merit increases and promotional increases, changes in length of work week or in basic wage scales, provisions for temporary increases in working staff (as by vacation replacements or summer hirings of technical students), and any other changes in personnel remuneration which may be foreseen. Adequate provision for such variations during the budget period will provide an accurate estimate of anticipated expenditures.

Since they will, in general, be only one-third to one-half as great as expenditures for labor, the expenditures for other than labor items need be estimated in less detail. Ordinarily it will suffice to examine the current rate of expenditure and make an over-all adjustment, in line with expected trends in the work, for items such as materials and services purchased from outside vendors, shop and craft work, travel expense, purchases from other departments, cost of utilities (steam, electrical energy, etc.), depreciation charges.

To obtain information on the actual percentage distribution of research expenditures, a questionnaire was sent to a number of industrial research directors. The fifty-three usable replies represented research organizations from very small to fairly large in some sixteen industries. Some of the replies were only partially usable because of variations in accounting practice.

The following table summarizes the data obtained, giving for each item of expense the number of usable replies (samples), the highest figure reported, the median of all figures, the lowest figure reported, and an indication of the grouping of figures around the median.

	No. of Samples	Percent Total Expense			
		High	Median	Low	Grouping
Labor	51	100	68	41	69% of samples in range 60–77%
Purchases	43	39	12	5	70% of samples in range 7–16%
Shop and Craft Work	32	26	4	0.2	78% of samples in range 1–8%
Utilities	47	8	2	0.1	64% of samples in range 1–3%
Depreciation	39	12	2	0.9	62% of samples in range 1–3%
Travel	46	8	2	0.2	74% of samples in range 1–3%
Miscellaneous	41	25	6	0.5	80% of samples in range 2–14%

While some of the "highs" and "lows" listed above no doubt reflect circumstances peculiar to the reporting organizations, it would seem reasonable to consider the medians and figures in the last column, as indicative of current practice.

The data summarized by the above table were also analyzed graphically in detail to ascertain whether the distribution of expenditures was dependent upon the size of the research organization or of the type of industry. No such relation was established.

The figures submitted to company management may be shown as anticipated gross expense of the department, anticipated credits to the department for services to other departments, and anticipated net research department cost. Ordinarily it will not be necessary or desirable to submit the detailed estimates which have been used by the research department in arriving at the gross figures, but it may be helpful to include details on variable services to be requested of other departments, such as utilities.

If the most recent previous budget also is shown and brief notes supplied as to the reasons for significant variations between previous and present budgets, management's consideration of the budget will be aided.

Consideration of items such as those listed above will provide a sound basis for budget estimates and also for comparison later with actual expenditures. For use of research management in planning the distribution of effort, figures should also be available showing the current rates of expenditure and anticipated variations classified according to whether the work is on one or another of the various products manufactured or to be manufactured by the company.

How Much to Budget [4 (Chapt. XI), 6, 13]

The question is often raised as to the amount which should be spent on research activities. The answer to this question is difficult to formulate because of variations in conditions from industry to industry, from company to company, and indeed within the same company at different times. Since the research expenditures are for the most part through the departmental payroll, it is apparent that the fundamental basis for setting the budget will be by determining the number and quality of employes who must be on the staff in order to carry out (1) desirable short-range work and (2) a reasonable amount of work with a longer-range expectation of application. The determination of the amount of short-term work which should be done and also of the amount of long-range work will depend upon the size of the company, the complexity of its operations, plans for or attitude toward expansion, rate of obsolescence of processes and products, and abundance of ideas for worth-while projects. Most research departments will take care to have sufficient formally authorized work ahead of them to carry the department for some time at the current or anticipated average rate of expenditure. Authorizations sufficient for six months' work would probably be a bare minimum and a desirable figure might well be one to two years. This of course will include a number of shorter-range projects and some of considerably greater duration. In addition, departmental thinking along the lines of broad programs may be expected to generate formal applications for projects and their authorization at a steady rate.

Most companies will be interested in comparing their research expenditures with those of other companies, particularly within the same industry, with due regard to the differences in size and scope of activity. Some companies have made such information available through their annual reports or press releases,[9, 10] but even when so reported, comparisons are difficult because of the lack of detailed information about the activities included under "research" by various companies. Extensive data have been published, however, on research expenditures in various industries as percentage of gross sales in an attempt to correlate the research expenditure with the magnitude of the companies' operations. For example,[8] in April 1940, member companies of the National Association of Manufacturers were asked what percentage of their normal annual gross sales income they spent for research. Usable data from 181 companies showed a median expenditure for industrial research equivalent to 2 per cent of gross sales income. The percentage was highest in small companies. When ranked according to type of industry, the chemical and allied products industries were highest in percentage of gross income spent for research. (A more detailed analysis is given in the reference.) Data [25] for a much larger number of corporations, however, indicate average research expenditures considerably lower, with electrical machinery and apparatus markedly in the lead.

Accounting Practice for the Research Laboratory: [1, 27] *To Account or Not to Account*

While many, or perhaps most, research managers are convinced that there is a net advantage in maintaining an accounting system for the work of the research department, there are some who argue vigorously against such a practice. Some of the disadvantages cited by the latter are the incentive to concentrate on the most easy and obvious problems,[19] the distraction from creative activities on the part of the research personnel if they give attention to cost matters, the lack of precision in the cost records because of the overlapping of research activities, and the cost of maintaining an accounting system. Among the advantages [2, 20, 26] of an accounting system may be cited the stimulus to closer definition of objectives; the more effective current control of the work; the availability of cost information for comparison with results; improved relations with company management; the providing of a basis for billing other departments for work which the research department does for them but which is not properly classified as research; and finally, the capitalization of such items of expenditure as should be so classified.

How Detailed an Accounting is Appropriate? [3 (p. 102), 7]

Accounting systems for research departments may be very general or very detailed, according to the needs of the organization and the benefits to be derived. The factors influencing a decision as to the degree of detail required in the accounting will include the size of a research organization, its relation to company organization, and its relation to other clients, if any. A small research organization, which does no service work for other departments and which does not sell or license its products to other companies, will require a minimum of accounting. A large research department, working on a number of projects with responsibility allocated to several division heads and through them to a number of group leaders, will in most cases find it desirable to have fairly detailed accounting methods. A research department which sells its services to other departments, and particularly one which sells the products of its research to other companies, will need accurate and detailed cost records as the basis for the charges it makes. The following discussion will assume a detailed cost accounting procedure. The revisions to adapt it for use by organizations preferring a simpler procedure will be readily deduced by those interested, and have been indicated by various writers.[10]

Classes of Accounts

Ordinarily the research department accounts will fall under one of three general classifications: income accounts, capital accounts, or expense accounts.

Income Accounts. This general classification will include relatively few accounts, as for example, income from services to other departments, income from license or sale of processes or products, miscellaneous income. It is usually considered important that these be *departmental* accounts and that no allocations of income be made to the credit of subdivisions of the department. To attempt to do so would seriously endanger morale. Adequate evaluation of the benefits of research activity is extremely difficult [17] but highly important.[2, 3 (p. 21–22), 12, 13, 18] It is discussed elsewhere in this book.

Capital Accounts. For convenience in accounting, the capital accounts for the research department's buildings and equipment will in many cases be handled in the general company accounting system rather than the departmental accounting system. In either case the usual records of initial cost, reserves for depreciation, and book value will be maintained. It is usual to place a relatively low figure on the length of life of experimental equipment because of its high rate of obsolescence. For many equipment items a life of five years will be a reasonable estimate. A life of ten years might be estimated for items of equipment suitable for use on many projects. Buildings are carried at the depreciation rate appropriate for the type of construction.

Expense Accounts. Because of the concentration of research expenditures under this heading, the subject will be treated in more detail. It is customary and convenient to make a distinction between direct costs and overhead costs.

Direct Costs. These are the items of expense which are chargeable directly to the work on a specific project. Each such project should be carefully defined as to objective and assigned an identifying account number. The same account number may also be used to identify the reports, memoranda, etc., recording the work on the project. The account number may, if desired, indicate the nature of the investigation by incorporating in the account number a numerical code descriptive of the product or process. Such a project would be authorized on a job basis with definite starting and stopping dates. Authorization of expenditures may be made by the research manager subject to endorsement by other interested departments and by company management in cases involving major expenditures or new programs. The life history of such a project would include: a statement of the justification for initiating the work; an estimate of the dollars and time required for the initial stage of the investigation; authorization of such an expenditure; the preparation of monthly reports of costs of the work and of progress on current work; justification and authorization of additional expenditures as required; a final report of the total cost of the project as against total authorization; and a final report of the results obtained.

For some long-range projects on basic topics it is impossible to estimate the final total cost at the inception of the project or during its early life. Such a project can be controlled by a series of authorizations at reasonable intervals. Attention is given to results obtained, modifications of objectives, and proposed attack at the time each authorization is considered.

The record of costs on the project should show expenditures for labor, and for other than labor, the latter subdivided to a degree suiting the circumstances of the individual research department.

The cost records may also be set up so as to answer the question: "Who spent how much on what projects?" In many cases, charges will be made to projects by service groups or others not directly under the responsibility of the group to which the project is assigned. A cost system such as this places the responsibility for expenditures and results on the supervisor directly responsible for the project and provides him with monthly cost figures for his use in guiding the work.

Direct Costs—Projects on an Annual Basis. It is desirable to authorize some work on a year-to-year basis, rather than as a distinctly defined job with a definite beginning and end. Examples of such work are: embryonic investigations covering a multitude of minor jobs; the development of miscellaneous research tools for general use of the department; internal service work and the development of analytical methods; service work for other departments not foreseeable item by item, but known on the basis of experience to average some fairly definite rate of expenditure.

The mechanism of cost accounting on such continuing projects is the same as for those on a job basis except that the authorizations are renewed or revised annually rather than being made for a period of time corresponding to estimated expenditures on a specified job or subdivision of it.

The discussion and authorization of appropriations for all projects on a continuing basis at the same time each year provide an opportunity to review critically the ratio of such expenditures to those on a job basis.

Overhead Costs—Projects on an Annual Basis. Research department expenditures, which are necessary to proper operation of the department but are not satisfactorily chargeable directly to experimental projects, may be grouped into an overhead classification and authorized on an annual basis in as much detail as desired. Some examples are: depreciation, vacation and other paid absence, building maintenance and repair. Some other items of expense, of which a portion may be charged directly to experimental projects, and the residue charged to overhead, are: supervision, safety activities, library expense, equipment maintenance and repair, miscellaneous supplies, utilities, miscellaneous travel, petty cash, etc. In explanation of the dual classification of these latter items, it may be pointed out that in direct supervision of a few projects, as compared to general departmental or divisional supervision, the cost of modifying equipment to make it safe for operation; purchases of books for specific projects; the repair of equipment necessary to put it back into condition of general usefulness; supplies for specific rather than general uses; power consumption by machines on specific projects; travel or petty cash expenditures in connection with the work on specific projects, are all chargeable to the projects involved.

It must be recognized that there is a tendency on the part of those coding charges, to charge to overhead rather than to direct project expense, and therefore some policing of the overhead is necessary. The points of view and practices of various research organizations with respect to items to be included under overhead, and the basis for decisions on borderline cases, make it useless to attempt to set up any average figure on a percentage basis for overhead. Such comparisons between research organizations could be made on a valid basis only by examination of the detail of the items so charged. A convenient way of making such an examination is to state the dollars overhead per dollar of direct cost, breaking the first figure down into as much detail as is required for the comparison.

The overhead figure has a practical use in determining the amount to be charged other departments for service. Such billings prepared on the basis of direct cost plus overhead come much closer to rendering the research department a fair return for its services than would figures of direct cost only.

Capitalization of Research Expenditures vs. Writing Off Currently[14]

Most research managers would prefer to see the annual expenditures of their departments written off as expense practically completed rather than capitalized. Primarily this is a reflection of the constant emphasis on new ideas and new approaches in their thinking and the reluctance to receive in the future residual charges for work which from the research point of view has long been completed and possibly already superseded.

From the research point of view, current work may well make obsolete the results which were obtained during the preceding year. In addition there are very real difficulties in establishing a sound basis for capitalizing research expenditures which may some years later prove to have an application with a return many times that of the original expenditure, or may be completely without return. In many cases it is impossible to determine whether work of several years' duration will have useful application until, or considerably after, the work is completed. The more fundamental or long range the program, the greater the uncertainty becomes. In some cases the work on a project aimed toward well-defined objectives, will produce, as a by-product, data of considerable value in an application quite unforeseen and remote from the original objectives. The whole program would not have been necessary to obtain these data if the possibility had been recognized, yet they would not have been obtained if the broad program had not led the work into the fruitful paths.

Because of these complexities, research people in general favor the writing-off of research expenditures as they occur.[6, 11, 14, 21] It is interesting to note the recommendation in the Bush report [5] that this be facilitated by amending the Internal Revenue Code.

Cost Control

The use of the cost accounting system as a tool in control of the departmental activities is effected through monthly reports prepared as promptly as possible after the end of the month and submitted to departmental management. These will include (1) a report of the expenditures on individual projects *vs.* the authorization on each, (2) a report of the departmental total expenditure *vs.* budget, (3) a report of departmental expenditures *vs.* departmental income credits. Because of month-to-month fluctuations the last-mentioned report may well be prepared to show not only the figures for the most recent month, but also figures for the twelve-month period ending with the current month.

The method of using the cost reports will vary depending upon the organization of the department and the preferences of the departmental management. In large research departments, a departmental budget committee may be charged with the responsibility of the month-to-month follow-up; preliminary review of applications for new or additional authorization; examination of trends in departmental expenditures; and preparation of departmental budget. Their conclusions and recommendations are transmitted to departmental management.

Since the major portion of research expenditure is for labor, and since the returns from research are directly related to the mental activities of research personnel, such a committee and the departmental management will make every effort to stimulate the formulation and prosecution by departmental personnel of projects in those fields having greatest possibilities for profitable outcome.

Administration of Accounting and Budgeting Activities

The supervision of the accounting work within the department, the follow-up of conclusions based upon the cost reports, and the relations with other departments on accounting matters, may be made the responsibility of an administrative officer of the department reporting directly to the manager. This would reduce to a minimum the attention which must be paid to the operation of the accounting system by those primarily responsible for execution of the experimental program.

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CHAPTER IX

Research Reports

The Need for Research Reports

Research activities do not follow desired channels without supervision. Adequate reporting of work progress and accomplishments is one important requirement for intelligent direction from the major control sources; first, the research director operating at close range in contact with current problems, and second, the company directorate or executive staff governing long-range plans and policies.

A moment's reflection will disclose the similarity between research progress and water flowing in a stream. The water moves on and on, slowly or swiftly, through rapids and into backwater areas. When specific objectives are desired the course of the stream may be changed by study and the application of engineering principles. Likewise the course and rate of productivity of research activities may be directed toward desired ends by study of work in progress and the results accomplished. No research director can personally observe all of the activities of a department. The research representative on the board of directors has even less chance. A comprehensive reporting system is the obvious answer.

One important objective of the reporting system is the furnishing of sufficient information to facilitate proper direction of research, development, and associated engineering activities. To this end, the reports reaching the administrative heads need to be factual, brief, and broadly informative. This type of report is prepared essentially for administrative use.

A second major factor to be given consideration is the type of report that answers the questions: *How? When? What?* and *Who?* and others of similar nature. Such reports are, in reality, the depart-

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This chapter by D. G. Smellie, Chief Engineer, The Hoover Co.

ment's basic permanent records which provide a fund of necessary reference material for future years. Again the reports must first of all be factual, then analytical, and generally must end with recommendations.

A third important reason for adequate reporting of activities might be called strictly selfish on the part of the research director and his immediate staff, for it embraces the philosophy of accounting for stewardship. It is found that, when analyzed, this philosophy does or should extend all the way down to the research individual. Although it is generally acknowledged that the researcher should be relieved as far as possible of the onerous job of reporting in writing, even he will realize that he has the obligation of passing on to his superior the results of his own activity together with opinions and recommendations thereon.

The individual should consider reports as a means by which he can establish his own merit. Members of the directive staff above him are less closely associated with the actual details of the individual's work and therefore progressively in greater need of clear, concise reports. A well-prepared and usable report often brings to bear upon the individual the specific attention of his superiors. These men also need such reports for another purpose.

Each individual in this upward chain from the worker to the research director has a responsibility for expense incurred. An adequate reporting system is of major assistance in clarification of executive thought with respect to research and development expenditures. These are treated fully in another chapter and so need be mentioned here only as a factor in the report problem.

Roughly speaking, expense is proportional to activity, and eventually there comes a day when financial reports disclose sizable expenditures which are likely to be compared with the expenditures of the revenue-producing departments. The administrative group or its representative in charge of research receives reports of expenses incurred. Since the research department is a non-productive or "overhead" department, it is important that easily formed adverse opinions regarding research expense be forestalled. This can be done by constructive reports from the research level.

It is obvious that, to avoid unfavorable comparisons, a cardinal requirement of a research administration is prompt and adequate reporting of progress toward the objectives for which the expenditures have been authorized. Favorable impressions of correctly directed and productive activity oil the machinery of research organizations.

Research Reports—Classified Broadly

It is clear that research reports fall into several broad classifications. For purposes of discussion these may be recorded as follows:

- *A*. Reports for administrative information.
  1. For the research director.
  2. For the management staff.
- *B*. Reports for record purposes.
- *C*. Reports for publication.

It should be pointed out that in the following discussions we make no attempt to lay down specific rules for the formulation of a reporting system that can be adopted as a whole. Each research group must formulate a system adapted to its needs. These will depend largely on the manner in which it works with the remainder of the organization and its type of administrative direction.

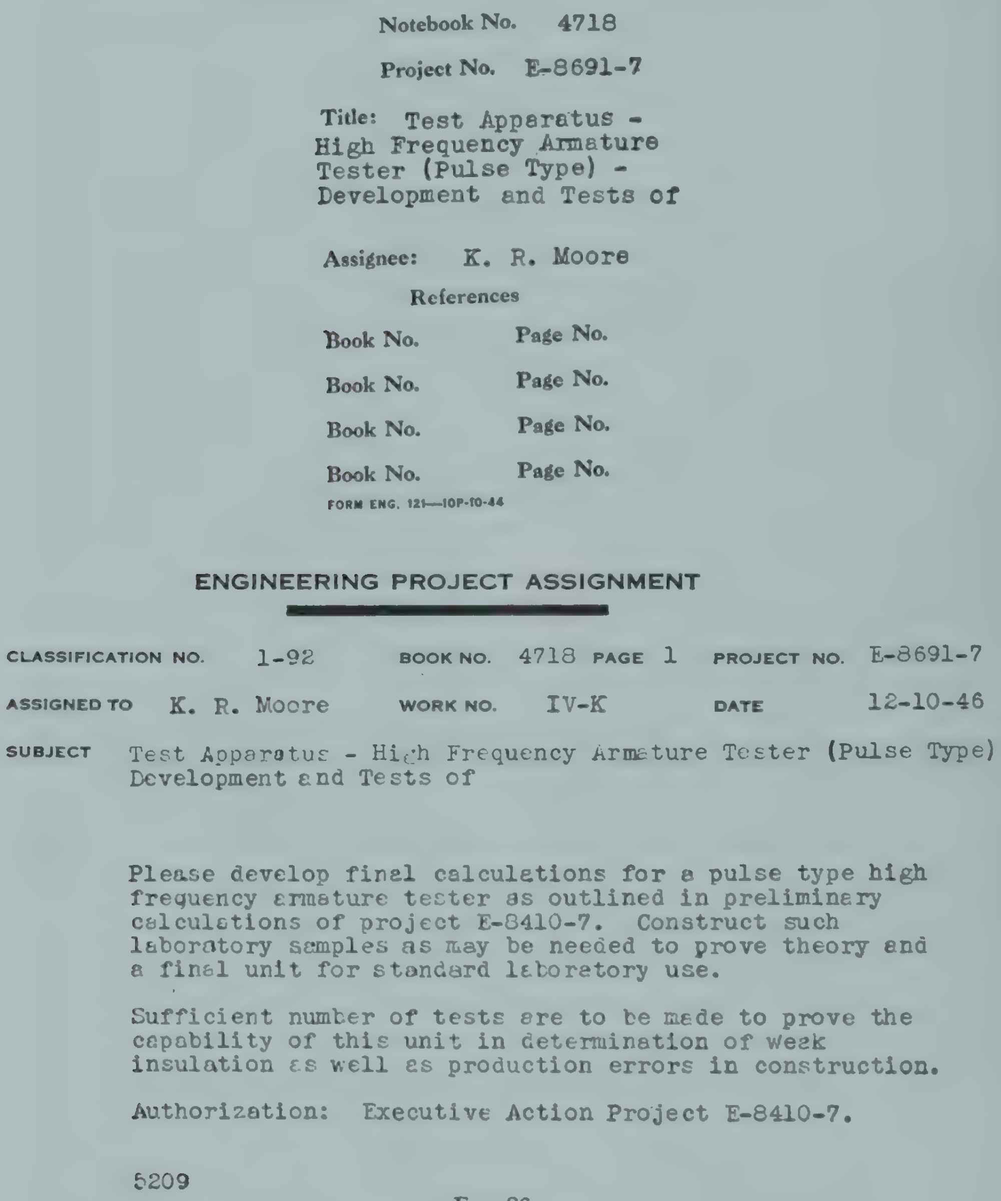
A research reporting system has been depicted as serving several distinct needs. To see how these requirements are fulfilled one can well start at the bottom by describing the customary building blocks, determining later how they may be combined. This takes us to the individual workman and his notebook records.

The Notebook—An Informal but Permanent Record

For the complete recording of the day-to-day activities of the individual it is accepted practice to provide each non-routine worker with notebooks having official status. Many types of suitable books exist. They may be single or multi-copy—both are used. The pages may be plain, ruled, cross-section ruled, or any other types that seem best fitted for the work in hand. The physical characteristics of the book such as size, paper, binding, and other details are of less importance than the status of the book as an official laboratory record, issued and identified with the assignment usually by serial number. Pre-numbered pages and a bound volume are preferable to loose-leaf pages. For examples, see Figure 26.

Explicit reference to the use of the notebook, its official issuance with a project assignment and instructions covering use, as contained in the section of the laboratory manual devoted to instructions for recording of work, serve to establish the record satisfactorily for future patent or legal reference, should this be necessary. A typical reference to the use of the notebook is quoted from a laboratory manual:

> The assignee will be furnished with a notebook to be used during the execution of the work. Copy of the assignment will be pasted in as first entry in the work record. . . . Assignee shall paste his copy of



Notebook No. 4718

Project No. E-8691-7

Title: Test Apparatus -
High Frequency Armature
Tester (Pulse Type) -
Development and Tests of

Assignee: K. R. Moore

References

Book No. **Page No.**
Book No. **Page No.**
Book No. **Page No.**
Book No. **Page No.**

FORM ENG. 121—10P-10-44

ENGINEERING PROJECT ASSIGNMENT

CLASSIFICATION NO. 1-92 BOOK NO. 4718 PAGE 1 PROJECT NO. E-8691-7
ASSIGNED TO K. R. Moore WORK NO. IV-K DATE 12-10-46
SUBJECT Test Apparatus - High Frequency Armature Tester (Pulse Type) Development and Tests of

Please develop final calculations for a pulse type high frequency armature tester as outlined in preliminary calculations of project E-8410-7. Construct such laboratory samples as may be needed to prove theory and a final unit for standard laboratory use.

Sufficient number of tests are to be made to prove the capability of this unit in determination of weak insulation as well as production errors in construction.

Authorization: Executive Action Project E-8410-7.

5209

FIG. 26.

> "Outline of Procedure" in his notebook as second entry following the assignment sheet. . . . Assignee shall record original observations. . . . All entries shall be signed and dated at the end of each working day.

Such treatment of the notebook establishes it as a basic reference in case of patent interference or future litigation. Responsibility for proper use of notebooks falls upon the supervisory staff. In the use of the notebook the first page devoted to any project could well bear copy of the assignment as indicated above. The procedure outlined, or some equivalent thereof, is desirable from the standpoint of starting the notebook with a copy of the official assignment. The origin of this assignment is of interest and should be discussed at this time.

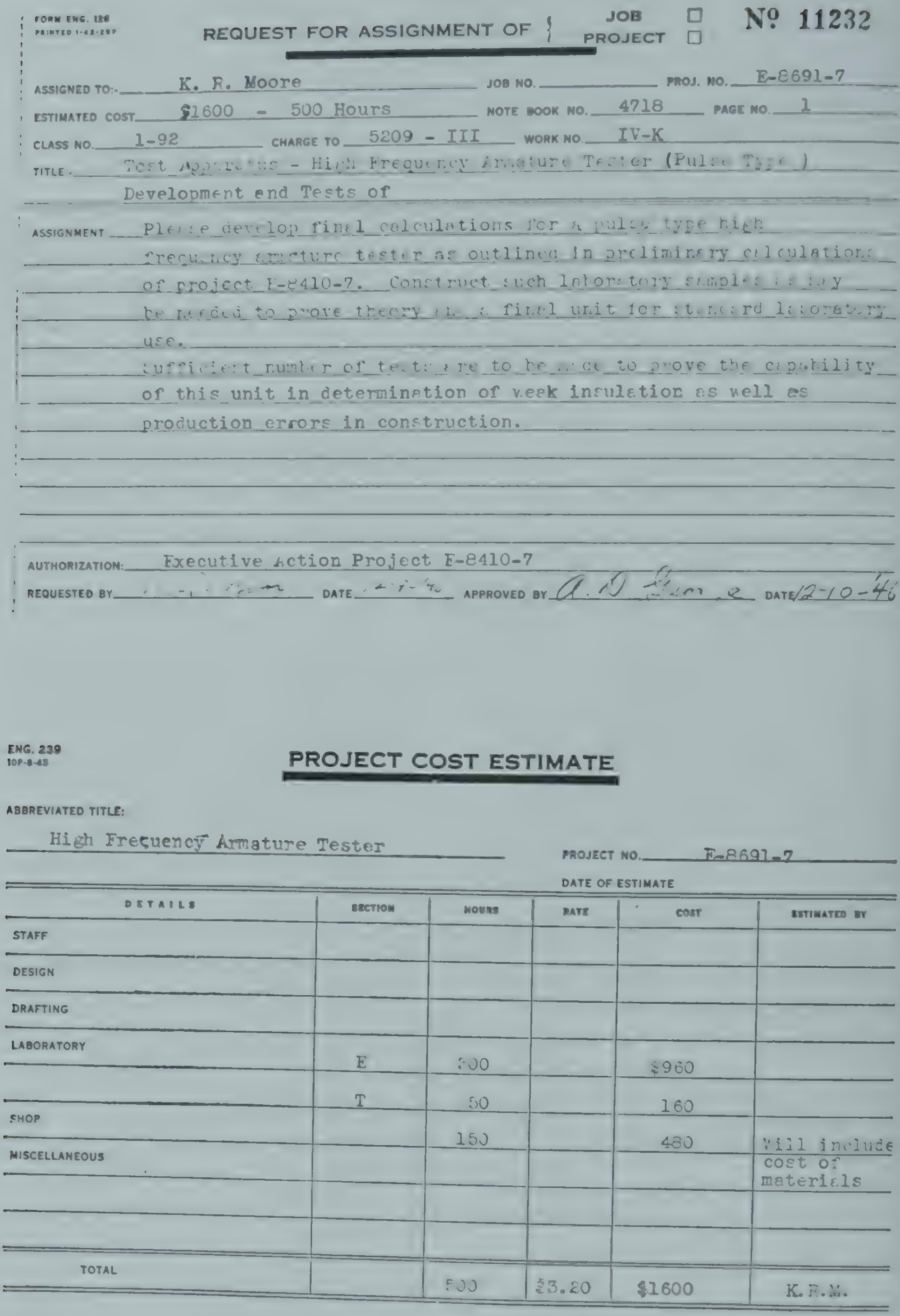
The assignment sheet, or equivalent mechanism for starting a new project, usually the first official record in multi-copy form, is an integral part of the record system by which development dates can be proved. Since it is often desirable to antedate this by a chronological history for patent interference purposes, the steps that lead to its issuance are of interest.

Actual issuance of a new project assignment may result from many causes. Recommendations in previously closed projects, discussions in work program committee meetings, management requests, all find their way into the assignment issuance channel. Actual approval of new work involving expenditure of funds is usually preceded by a discussion of proposed work by the research director and the staff member, such as a section chief, who will be in charge of the work.

When there appears to be complete agreement on intent and extent of the work proposed, a check is often made by the simple device of having the section head prepare the text of the assignment for final approval by the research director. This gives the director a chance to evaluate his lieutenant's understanding of the problem.

When this project assignment text receives the approval of the research director, it starts through the clerical and accounting routine that places it on work programs, assigns charge numbers, and work and subject classifications. Eventually the necessary copy or copies are delivered to the section head for discussion with his individual or group workers to be assigned to the task outlined.

For illustrations of (*a*) typical "Project Request" form that section heads make out and (*b*) resulting project assignment sheet, see Figures 27 and 28.



FORM ENG. 128
PRINTED 1-43-2??

REQUEST FOR ASSIGNMENT OF { JOB ☐ PROJECT ☐ }

Nº 11232

ASSIGNED TO:- K. R. Moore JOB NO. PROJ. NO. E-8691-7

ESTIMATED COST $1600 - 500 Hours NOTE BOOK NO. 4718 PAGE NO. 1

CLASS NO. 1-92 CHARGE TO 5209 - III WORK NO. IV-K

TITLE. Test Apparatus - High Frequency Armature Tester (Pulse Type)
Development and Tests of

ASSIGNMENT Please develop final calculations for a pulse type high frequency armature tester as outlined in preliminary calculations of project E-8410-7. Construct such laboratory samples as may be needed to prove theory and a final unit for standard laboratory use.
Sufficient number of tests are to be made to prove the capability of this unit in determination of weak insulation as well as production errors in construction.

AUTHORIZATION: Executive Action Project E-8410-7

REQUESTED BY DATE APPROVED BY A. D. [illegible] DATE 12-10-46

ENG. 239
10P-8-45

PROJECT COST ESTIMATE

ABBREVIATED TITLE:
High Frequency Armature Tester

PROJECT NO. E-8691-7

DATE OF ESTIMATE

DETAILS	SECTION	HOURS	RATE	COST	ESTIMATED BY
STAFF					
DESIGN					
DRAFTING					
LABORATORY	E	300		$960	
	T	50		160	
SHOP		150		480	Will include cost of materials
MISCELLANEOUS					
TOTAL		500	$3.20	$1600	K. R. M.

FIG. 27.

ENGINEERING PROJECT ASSIGNMENT

CLASSIFICATION NO. 1-92 **BOOK NO.** 4718 **PAGE** 1 **PROJECT NO.** E-8691-7

ASSIGNED TO K. R. Moore **WORK NO.** IV-K **DATE** 12-10-46

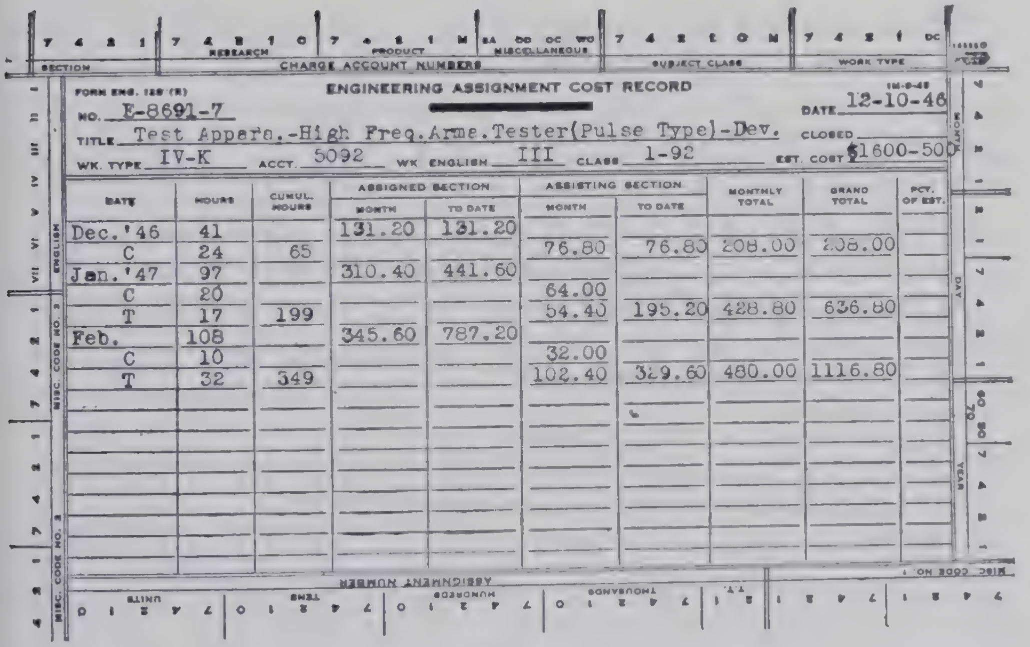
SUBJECT Test Apparatus - High Frequency Armature Tester (Pulse Type) Development and Tests of

Please develop final calculations for a pulse type high frequency armature tester as outlined in preliminary calculations of project E-8410-7. Construct such laboratory samples as may be needed to prove theory and a final unit for standard laboratory use.

Sufficient number of tests are to be made to prove the capability of this unit in determination of weak insulation as well as production errors in construction.

Authorization: Executive Action Project E-8410-7.

5209



SECTION — CHARGE ACCOUNT NUMBERS (RESEARCH, PRODUCT, MISCELLANEOUS) — SUBJECT CLASS — WORK TYPE

FORM ENG. 128 (R)

ENGINEERING ASSIGNMENT COST RECORD

NO. E-8691-7 DATE 12-10-46

TITLE Test Appara.-High Freq.Arme.Tester(Pulse Type)-Dev. CLOSED

WK. TYPE IV-K ACCT. 5092 WK ENGLISH III CLASS 1-92 EST. COST $1600-500

DATE	HOURS	CUMUL. HOURS	ASSIGNED SECTION		ASSISTING SECTION		MONTHLY TOTAL	GRAND TOTAL	PCT. OF EST.
			MONTH	TO DATE	MONTH	TO DATE			
Dec. '46	41		131.20	131.20					
C	24	65			76.80	76.80	208.00	208.00	
Jan. '47	97		310.40	441.60					
C	20				64.00				
T	17	199			54.40	195.20	428.80	636.80	
Feb.	108		345.60	787.20					
C	10				32.00				
T	32	349			102.40	329.60	480.00	1116.80	

ASSIGNMENT NUMBER — MISC. CODE NO.

FIG. 28.

Daily entries concerning the work in hand with references to progress made, discussions with other members of the staff or persons outside of the organization, sketches of apparatus set up, photographs, data tables, and similar entries comprise the raw material from which further reports are compiled. Each day's entry should be signed and dated. Witness signatures are not considered essential for daily routine but in case of developments regarded as important, witness signatures may well be used.

On the last page, completed books should bear a reference to the continuance of the work in another book, which should be issued officially to complete the record. These records are among the most valuable from the patent standpoint and in many laboratories are preserved intact. Partially used books may be reissued for another project and filed when all pages have been used. In some cases pages are cut out, stapled together and kept with other records of the project, thus freeing a partially used book for additional service. Preservation of the book intact is considered preferable.

Before taking up the subject of more formal reports based upon the subject matter contained in the notebook, it may be well to record the current thought regarding the laboratory notebook: that it is an informal record which may be kept as the individual desires with the limitation that it must be legible and complete enough to tell the whole story. From this beginning we proceed to formal reports on the project.

The Project Report—A Formal and Permanent Record

In contrast to the informality of the work-record notebook there comes a time when that which has been deemed worth doing and for which expense has been incurred must be written up in a formal report. From the standpoint of the director of a laboratory there is no question about the necessity for the preparation of these reports, but without proper explanation his views on the matter are often questioned by the working staff, especially by the man who has just completed the work and is anxious to get on with the next phase of the problem. For the benefit of the individual worker it should be pointed out that the technical report is the culmination of his activities on an assignment. In years to come, it may constitute the only full and complete record of what was done, together with results accomplished.

Over a period of years personnel will change. Specific recollections of things done or impressions gained are likely to become distorted if not lost. It is obvious that the only reliable history of a laboratory's activities is in the written records and that such history is only as complete as the reports. The quality of these records is determined by the day-to-day activity on them. So it is important to consider the project report, prepared upon the completion of any phase of activity, as the formal termination which will serve then and in future years as a complete exposition of the object for which the work was undertaken, of procedures followed, of equipment used, of results obtained and of the use made of them.

The project report is generally considered a record for internal use only and may be so prepared. When limited to internal use, the subject matter may include confidential matter that would not be permissible if the report were to pass into the hands of persons outside the organization or without the proper background for interpretation. Upon occasion it will be found advantageous to use these technical reports externally. When this is known in advance, suitable instructions regarding unusual usage should be issued before the preparation of the report.

There have been many opinions as to the length of time that a project might continue in the laboratory without preparation of an official report. Even now, after years of discussion, no uniformity of opinion appears, but on several items there is partial agreement. When work has been terminated on an assignment, the report should be prepared without delay. Prompt rendering of reports creates a good impression and is beneficial to all concerned. Undoubtedly it is the best procedure from the technical standpoint, for delays frequently mean that some items will be forgotten or be reported as matters of opinion instead of fact.

Many organizations use one year as a maximum period that a project can remain open. Even though the original plan for the work may not have been completed, if a project has reached a point that suggests a complete report of activity up to that time, it should be prepared. It may, of course, be unwise to try to summarize at that time, in which case the report would take on the character of a mid-term report, with postponement of full details and conclusions until the completion of the activities under a succeeding assignment.

The formal report should contain a copy of the assignment as its first entry. If, during the life of the assignment, it has been found necessary or advisable to change the wording or any other detail of the assignment, both the original and the revised assignment should be given in full. The reason for such action is to depict clearly, at some future time, that the course of the investigation was changed officially with full substantiation of the difference in assignment text, with dates, authorization, and other pertinent details.

The body of the report can follow normal report outline. Technical reports as a whole vary but little and usually comprise the following items:

Introduction and explanatory material (Usually to establish a background for the reader)
Subject (A re-statement of the problem and the desired objective, usually somewhat more in detail than the assignment)
Reference to previous and/or related work
Descriptions of materials, products, processes, etc., used in the work covered
Special equipment (Illustrated with photographs if advisable)
Operating procedure
Results, data tables, charts
Analysis and comments
Conclusions
Author's recommendations
Author's signature and *date of completion of activities*
Section head's or supervisor's comments
Executive action and disposition
Final approval by authorized parties
Appendix (Limited to collateral material not necessarily a part of the report but desirable for review purposes especially if duplication at some future date might be difficult)

Such a list of report subdivisions appears formidable. They are required only when subject matter is so complex as to indicate that full organization of material be used. In some instances various subdivisions can be omitted or several subdivisions can be combined. Generally this is possible only on projects of limited extent. The section heads or work supervisors, making the first review of the report as formulated by the individual, should be charged with the responsibility for the use of full or partial outline as the subject matter would seem to indicate.

The Summary

Note that no mention has been made of a summary. Research directors do not have the time to review long reports in detail, yet for proper execution of their own jobs they must keep abreast not only of results obtained, but of the manner in which their staff members are doing the work. If carefully prepared and well organized with this objective in mind, a summary can serve adequately to give a complete picture of the work and its results.

One outstandingly successful procedure that has been developed should be mentioned. Instead of a summary, as such, the subject matter of the long report is condensed into two or three typewritten pages, including such figures or photographs as are necessary. To this condensation by the project writer there is appended a record of the formal executive action taken, and official closure.

This complete but abridged story is then introduced into the report as a summary. It appears immediately behind the assignment sheet and if the story as presented in this condensed version is satisfactory, the reader may ignore the remainder of the material with a great saving of time. The body of the report need not be reviewed unless one wishes to see the manner in which the work was conducted and explore the data upon which final conclusions were based.

The Condensed Report

Frequently it will be found that the entire story of the assignment can be told in the so-called "condensed report" without the necessity of appending a detailed report. In actual practice this amounts to elimination of all but the summary. Supervisors of work should be responsible for the inclusion of sufficient data so that the complete story is told with the assurance of reproduction of the work at some future time should this be necessary.

An additional advantage of the condensed report is that copies can be circulated among the supervisory staff to give them a full story of the work that has been done and results accomplished. Research work in the library is also facilitated.

Inasmuch as the technical reports are preserved for permanent records, it is preferable that they be prepared with as many copies as conditions indicate. It is considered good practice to keep two official copies, rather widely separated for preservation in case of fire. A third working copy can be routed to the library and upon occasion a fourth copy can be used to advantage in the originating section. Inasmuch as most of the data in these reports are considered confidential, however, the practice of keeping extra copies in the section is not to be recommended since control is likely to be less carefully maintained here than if the library were responsible for the working copies.

In laboratories handling subject matter of confidential nature, it will be found advantageous to keep the number of copies to a minimum, thus reducing the chance that one will find its way into the hands of persons not authorized to receive the information.

Miscellaneous Reports

The day-to-day activities of any research or development group involve many conferences and occasions upon which it is seemingly in order to prepare a special report. In conferences the distribution of personnel is varied, opposing viewpoints are discussed, visitor's comments are received, decisions reached, and instructions issued. Experience soon demonstrates that interpretations and recollections do not agree. The need for official record keeping is obvious.

Inspection of the problem often indicates that certain types of conferences occur frequently. Among these are:

1. Internal conferences (those attended by department members only, or by members of two or more departments but still within the company structure).
2. External conferences (reports of discussions with visitors, reports covering inspection of external plants or laboratories, etc.).
3. Periodic meetings of special committees.

All such conferences should be covered by preparation of reports serially numbered under some identifying key or code. Each report should bear appropriate title, date of conference, and a list of the participants; it should be terminated with the name of the report writer, the date of the preparation of the report, and the distribution of copies.

Since these reports often contain information that is not recorded in detail elsewhere, official copies should be preserved by the library or other record-keeping body just as in the case of notebooks and project reports. While illustrative subject matter is seldom applicable to actual problems in hand, several typical titles are given below.

Report Title	*Designation*
Works Management Committee Report	WMC-19
Research Program Committee Report	RP-67
Plant Visitation—Ajax Manufacturing Co.	O-149 *
Field Service Trip Review	I-92 †

* O = Outside Visitors or external trip report.

† I = Internal conference report.

Similarly it is considered good practice to use a special designation for the miscellaneous reports that accumulate in spite of the best intentions. The unidentified "memorandum" has been the bane of many a file girl's life (it is usually in the file but clipped to the back of some letter on an entirely different subject). Insistence on the use of special identifications for the unusual report, not readily classifiable elsewhere, will simplify location in future years. Some examples:

Production Quality Control by Statistical Methods.
Final Report on Inventions, Contract NOrd ....
Report on Salvage Procedures, Waterloo Plant.
Crack Failures in Die Casting Dies—Preliminary Report.
Manufacturing Cost System—Suggested Changes.
Standard Service Procedures.

Note that the titles listed above indicate subject matter other than conferences. Such segregation is not necessary but it will generally be found helpful to cover all conferences in certain types of reports, thus establishing a formal segregation of subjects.

Usually the reports can be informal, with wide discretion as to brevity or completeness depending on the need as seen by the supervisor of the activity. A plant visit for the purpose of bringing back information usually indicates the need for a somewhat detailed report, perhaps illustrated with photographs.

The distribution of both internal and external reports is advisedly controlled somewhat closely, since participating members often speak freely and the reports are intended to be a factual presentation of all sides of the discussion. Inasmuch as many of these reports must be prepared before final conclusions are reached, it may be advisable to restrict the circulation. Many research and engineering reports not prepared for general circulation have been misinterpreted because they got into the hands of people having only a portion of the story. When it is known beforehand that the report is to be distributed outside of the department for some specific purpose, the report can be scrutinized by the research director before it is issued. When it has passed this scrutiny and is ready for issuance, it may be considered an official interpretation of research or engineering opinion and thus serve as a basis for action by external departments.

A word of caution is required. All report writers—or, even better, an official report reviewer—should be vested with the responsibility for adequate titling of reports to promote proper indexing and filing. Experience has demonstrated that it is undoubtedly better to have proper titles than to pass a badly titled report on to the library for indexing and filing.

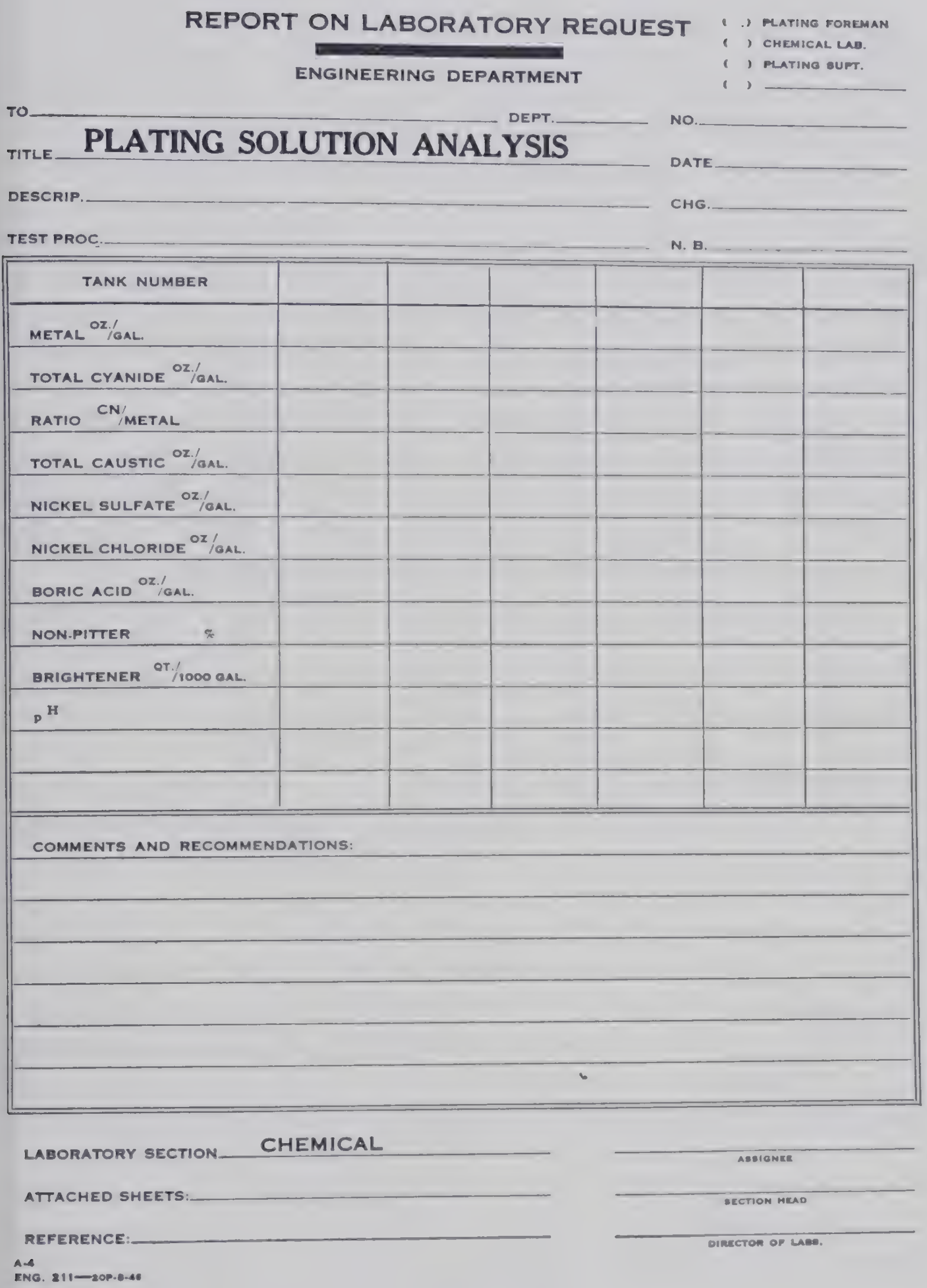
Operational Records

Once a laboratory is established it soon becomes apparent that there are certain more or less routine operations that must be performed. This type of work appears in the program more often if the laboratories are so located that they receive requests for production control assistance. Since there is no apparent need to cover this work by the formal reporting system, it can well be considered a class of activity for which purely operational records will suffice. Study of the requirements will generally indicate that appropriate forms can be devised. These, when filed according to serial number or such other designation as may be appropriate, will serve as a complete history of the work—origin, execution, report, and permanent record. Such systems must be devised to fit the particular laboratory and source of this routine work; so specific forms of records are not presented. Advantageous methods of handling such problems will develop when the problems are studied. (See Figure 29.)

Invention Records

Any research or development record may form the basis for subsequent patent action. The details of patent procedures must of necessity vary widely depending on the manner in which the company or research organization carries on its patent affiliation. An important "first" in any case is full and proper recording of research or development activities. Much has been said in previous writings about the necessity for maintaining the original records. The almost universal practice of providing official laboratory notebooks issued with each work assignment and properly identified therewith has been described. These notebook records, signed and dated as they are made, are acceptable as original records for patent applications and interference actions.

No matter how the final patent work is handled, provision should be made for periodic review of all departmental activities to select



REPORT ON LABORATORY REQUEST

ENGINEERING DEPARTMENT

( ) PLATING FOREMAN
( ) CHEMICAL LAB.
( ) PLATING SUPT.
( ) ____________

TO____________ DEPT.______ NO.______
TITLE PLATING SOLUTION ANALYSIS DATE______
DESCRIP.____________ CHG.______
TEST PROC.____________ N. B.______

TANK NUMBER						
METAL OZ./GAL.						
TOTAL CYANIDE OZ./GAL.						
RATIO CN/METAL						
TOTAL CAUSTIC OZ./GAL.						
NICKEL SULFATE OZ./GAL.						
NICKEL CHLORIDE OZ./GAL.						
BORIC ACID OZ./GAL.						
NON-PITTER %						
BRIGHTENER QT./1000 GAL.						
p^H						

COMMENTS AND RECOMMENDATIONS:

LABORATORY SECTION CHEMICAL

ATTACHED SHEETS:____________

REFERENCE:____________

____
ASSIGNEE

____
SECTION HEAD

____
DIRECTOR OF LABS.

A-4
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Fig. 29.

for patent consideration those items thought to be novel and worthy of patent investigation. Since it seldom falls within the province of the research director or any of his men to know what is new and novel or what subject matter may have patent implications, it is considered good practice to have the results of all work reviewed by an individual or by a group qualified to work with the patent representative in selection and recommendation of certain items for further attention by the patent department. In small organizations a single individual may be trained in this field. As the organization increases in size and subject matter becomes more varied, this responsibility for the selection of material to be given patent consideration usually devolves upon a committee composed of representatives of the various groups, said committee reviewing all research findings and the results of development work. When the laboratory is fortunate enough to have associated with it a patent department maintained by the company, the experience of the patent department can be used most effectively in this preliminary examination.

It is the responsibility of the research director to see that in all cases the records of work performed are so devised and handled as to present for patent review all items that might contain records of invention.

Progress Report

So far this discussion of reports and records has dealt with the creation and preservation of items that, in the aggregate, make up the permanent record or history of the organization's activities. They are the result of daily activity but reported at intervals, mainly upon the completion of the work in hand.

The research director and certain of the company officials need a different type of report to assist them in the interpretation of current progress. It is an accepted fact that one must be informed in order to direct. In an organization of any size it is impossible for the director to review each project frequently and in person. There is thus a need for a periodic report on the current assignments. This report will hereafter be called the Progress Report. Essentially, the progress report is the means for keeping the administrative group informed as to trends resulting from active projects. It should be issued promptly and often. The exact schedule can be determined by the individual organization.

While there is general agreement that such a report is required, there has been much discussion among research directors as to frequency of issue and the extent to which a report should cover current work assignments. Opinions on time intervals between reports vary from one week to two months, with many recommendations for the two-week and monthly intervals. It is suggested that the interval be determined by each organization according to its needs. The personal characteristics of the research director and the supervising company officials to whom the report may go are important factors in this decision.

Another much discussed question mentioned above is the extent of coverage. This depends largely on the mechanism through which the report is gathered and placed in final form. This progress report, which offhand may seem to be an item of transient interest only, assumes real importance when considered for its desirability as a permanent record. When prepared as a comprehensive report (covering all assigned projects and current investigations) it forms a chronological record of activity and is *news* as the reports are issued. From the standpoint of the permanent record it becomes an officially reported and chronologically dated history. Experience has demonstrated the high value of this history in many interference proceedings instituted by the patent office to determine priority of inventorship claims. It is frequently of use in establishing the dates of other time-related events.

No rule for coverage can be given. It must be worked out by each research director. All major accomplishments should be reported, but in contrast, no one—least of all a busy research director or research representative on the management's staff—wants to read a long list of "temporarily inactive" items. It is hoped the following discussion will indicate the latitude that may be taken in determining extent of coverage.

Because of its frequency of issuance, this report is often maligned and considered a great bore by the research personnel. One of the underlying reasons is that opportunity for recording real advances or spectacular results is seldom afforded. In spite of this handicap, the progress report is considered by some directors of research to be the most important report in the entire system. The basis for this feeling is that such a report affords opportunity to keep the subject of research activities and their results continually before the administrative group. For this reason it should be prepared carefully, with the ultimate objective always in mind.

Reports to Section Heads

The individual research men are asked to report informally to their section chiefs or other personnel supervising their work. This report from the individual may be as informal as is consistent with the established research system. It may even be a longhand statement in the official notebook covering the work in hand. This report by the individual should cover *all* assignments and activities. The informal reports by the individual workers can be combined by the section chief into a formal report for the section. The section chief may eliminate certain inactive items but in so doing he assumes responsibility for securing future action. In an extension of the correlating activity, the various section reports can be edited to avoid duplication; the resulting subject matter forms the official report which is issued by the department. If editing is a part of the official plan, it should be done by a competent but impartial individual, responsible to the research director only.

Appropriate editorial opinion by qualified parties forms an important part of the report. It may be included in the report as a routine matter or upon occasion it may accompany the report in a letter of transmission; this choice of action depends upon the desirability of having the comments reviewed by the lower echelon of the supervisory staff.

There are divergent practices in research laboratories that should be pointed out in connection with the progress report. In some organizations it is believed good practice to circulate the official departmental report to all members of the supervisory staff making formal contribution thereto (at least down to section heads). In other organizations the circulation is limited to the top supervisory group. It is evident that the extent of circulation is a matter of opinion to be settled by the research director, but the consensus seems to favor the course that keeps the entire supervisory staff fully informed as to the progress of work in the organization.

The language of the report should at all times be simple and direct. Figures or results quoted should be accompanied by a statement of recognized standard or other yardstick of comparison for adequate interpretation. This precaution should be based on the realization that the readers to whom the subject matter is addressed have other duties and cannot always be conversant with the many standards that may be in use.

In addition to the current transmission of information to the administrative group, the progress report has an important internal function. Alert research directors will sense the trend of investigations and encourage or re-orient project activity as may be required. The administrative group can follow closely the progress of work and make such changes or plans as may be necessary in associated company activities.

Taking everything into consideration, it may be said that the progress report is probably the most important and valuable one issued by any organization. It does many things:

1. Reports, while they are news, developments that may change the current thought with respect to work programs.
2. Discloses long-term trends.
3. Discloses lack of attention to assignments.
4. Becomes chronological history.
5. Forms a splendid source of raw material for the annual report.

Annual Report

While the annual report is largely of historical significance, discussing as it must action completed up to some "termination" point prior to the preparation of the report, it provides opportunity for a résumé of activities, with appropriate arrangement of the year's work in a single story or related descriptions, which disclose the progress for the year and its implications. Such a report can also serve to record the continuity of action over a number of years and in many instances has been found to be a most useful reference volume for the research director.

To facilitate administrative review the subject matter should be treated with simplicity and in straightforward discussions. Except where necessary the exclusion of highly technical material is indicated, since the requirements for technical discussions are fulfilled by the actual reports covering work accomplished.

Whenever the subject matter lends itself to such treatment, reports can be enhanced by liberal use of photographic and explanatory chart material. If the primary object of the report is kept in mind during its preparation, with effort concentrated on the presentation of a clear historical picture of the year's activities and the bearing that such results have had or can have in the future upon the company's welfare, it is probable that a good job of reporting and displaying the results of research activity will be accomplished. The interim progress reports submitted throughout the year serve to keep the administrative group informed. When properly edited and accompanied by the director's comments, they formulate administrative opinion. A good annual report can and should be the capsheaf of this activity.

The usual procedures in preparation and presentation of formal documents apply in this case. Reports should be beyond criticism in regard to composition, format, and binding. Complete indexing facilitates reference and should always be a part of the undertaking. Many companies present their annual reports as bound volumes. For future use the proper binding of an annual report is almost imperative. Hence, the expenditure might well be made at the time of presentation to the administrative group. The number of copies to be prepared and their distribution are matters that depend on local conditions and must be decided by the research director.

The annual report can be considered an accounting of the stewardship of the research and development activities by the formal head of the department. In general, the purpose of the report is to answer, for the management, a series of questions which they have a right to ask and which they should expect to have answered. The following questions are typical:

1. What did we do last year?
2. Did this activity merely keep us abreast of our competitors or did we gain on them?
3. Was this accomplished through—
    - *a.* New products released to production?
    - *b.* New products in process of development but not released?
    - *c.* Improvements in production processes, to reduce the cost of the product?
    - *d.* The acquisition of new personnel?
    - *e.* The development of existing personnel?
    - *f.* New equipment and expansion of facilities?
4. What contributions did we make to scientific progress—
    - *a.* Membership in scientific societies and the attendance record at meetings?
    - *b.* Active participation in scientific meetings?
    - *c.* Preparation and publication of papers?

If the idea of stewardship is made a part of the annual report, as it should be a part of all progress reports, it will be of material assistance in the preparation thereof.

Philosophy of Reporting and Record-Keeping

Now that we have described the common building blocks of a reporting system—admitting that many others may be required by special circumstances—this may be an opportune time to consider for a moment the philosophy of reporting which has been touched upon from time to time in the previous discussions.

The idea of stewardship is so obvious that it can be used to advantage in all discussions with report-writing individuals on the subject of report preparation. The opportunity for personal advancement through recognition of the individual by his superiors is a potent argument and if used correctly can contribute to the success of any report and record system.

The questions "How often?" and "How extensive?" must of course be settled by the directing organization of the research department in accordance with necessity, as it is determined for any particular organization. A cardinal feature is the ever-present requirement that a full and complete record, which will stand the test of future requirements, must always be maintained. This factor is important, since the value of any record of past work is only as good as the degree to which it fulfills the requirements of future use. Adequacy of reporting is a subject open to discussion, but if the organization practice is to visualize as far as possible the needs of the person receiving the report, distinct progress in reporting usually follows.

Reports for Administrative Information

In the foregoing descriptions of various typical reports, it was indicated that while certain ones were prepared specifically for administrative purposes, others were largely for record purposes. A grouping of the various reports under these two headings will show an overlapping or dual function for some types of reports. The following list of reports will indicate this dual function.

Reports for administrative purposes:

1. Progress report.
2. Certain of the special conference and other miscellaneous reports.

3. Annual report.

Reports for record purposes:

1. Routine operational records. (These are retained but not customarily reviewed by management due to the routine character.)
2. Notebooks.
3. Project record.
4. Miscellaneous reports.
5. Annual report.

The lists given above are typical but will need alteration to fit the requirements of various laboratories and development organizations.

Reports for Publication

Frequently reports prepared for internal use are of such a nature that publication is considered advantageous. In these cases it is a wise precaution to review the report, rewriting as necessary to eliminate idiosyncrasies of any particular reporting system that might cause confusion in the minds of uninformed readers, and adopting commonly used terminology, if the report contains locally developed expressions of questionable import to the reader outside of the organization. The report should also be examined critically for the disclosure of information which is considered confidential and therefore belongs only within the organization.

When it is known beforehand that publication of a particular forthcoming report may be desired, adequate instructions and precautions covering the points mentioned, and others of similar nature, can be given to the report writer.

General Comments Upon Report Writing

There are a few general comments that can be made to advantage in connection with the whole subject of research and engineering report writing. Accepting repetition for the sake of emphasis, the following highlights are set forth:

1. *Stewardship and accomplishment.* In general, the reporting system should cover adequately the subjects of stewardship and accomplishment. If the records and reports are not complete and intelligible to all who receive them, discussion of the report subject matter with the writer by the superior to whom the report has gone frequently has beneficial effects. In many instances the writer does not visualize the needs of the recipient. Reports prepared in terms that are familiar are always more acceptable.

2. *Make it simple.* With the clearly-defined trend toward management activities in research by persons other than technical experts and, in many instances, with even less technical knowledge in the admin-

istrative level of company structure, the need for reports in non-technical style and language is increased. The day of the highly technical or scientific report as a medium of communication between technical staff and the administrative group has long since passed. Such a report with a display of technically correct but unfamiliar terms is more likely to form a barrier between administration and research than to increase sympathetic understanding.

3. *Make it complete.* Completeness in reporting must be tempered by judicious omission of the nonessential. Permanent records upon which litigation or the repetition of experiments must depend should always be complete and sufficient in detail for such uses. It is more in the field of reports for administrative aid and information that the judicious elimination of nonessentials can be of greatest advantage to the report reader.

4. *Do it now.* A report that drifts along two weeks after a conference creates a bad impression. This is especially true if the report contains items assigned to various individuals for execution. All conference reports should be issued as promptly as possible after the termination of the conference. Progress reports should be issued on a uniform schedule and the annual report should be available as promptly as possible after the end of the period covered by the report.

5. *Avoid duplication.* Extensive research projects that require the services of more than one operating group often suffer from overlapping reports. Although at the expense of the personal pride of the original reporter, it is frequently found advantageous to gather the story from the various sources to produce a far more interesting and instructive report to the reader than a series of separate reports or duplication of subject matter within a single report would be.

6. *Save time.* Relegate to the field of operational reports such subjects as clearly belong in that field, thus relieving the staff of the writing of these reports for subsequent review by other parties. Both activities are time-consuming and unnecessary.

Résumé

Adequate report preparation and record keeping is an essential activity of any research and development organization. No hard and fast rules for its conduct can be formulated. The preceding discussion indicates the type of reports found in many organizations. Final choice must be made by the research director after an analysis of requirements. In broad terms the record and reporting systems serve two functions: the first, historical and the second, the furtherance of control both within the research organization and upward through management levels. A record and reporting system is a living thing, demanding constant scrutiny and revision as conditions change. The manner in which it serves is a measure of the research director.

CHAPTER X

Characteristics of the Research Man and the Research Atmosphere

The fact that the very core of any research structure, the ultimate criterion of the success of any research organization, and the real figure of merit of the research process itself lies in the character, ability, and performance of the research worker is so self-evident that even to mention it is trite. Yet obvious as this fact appears to be, it is nonetheless sometimes forgotten in research administration, and it is of such cardinal importance that it may bear repetition and continuing scrutiny, for upon its consequences a very large part of the effectiveness of that mixture of science and art that is research administration must depend.

This being true, it becomes of prime importance for the research director to analyze and understand the characteristics of his own research staff in particular, and those of scientific research men in general to two ends: first, that he may build up as competent and productive a staff for his laboratory as is humanly possible; and second, that he may provide for this staff an atmosphere in which to work that will be conducive to its sense of satisfaction and security, its efficiency and over-all productivity, its loyalty and happiness. For upon these qualities and conditions the ultimate success or failure of a research laboratory will very largely depend.

In the following pages are some comments upon the characteristics of the research man and the qualities of a desirable research atmosphere. These comments are based upon observation and the operation of various research laboratories abroad, and upon observation and experience in a number of academic and industrial institutions within the United States.

This chapter by C. P. Haskins, Director, Haskins Laboratories.

The Research Man: Traits of Character

Certain fundamental qualities appear to characterize virtually all research workers and to be more or less essential to the successful prosecution of their profession, regardless of how widely their work may differ or how much they may vary in other particulars. First of all, the scientific worker must be inherently of an investigative and inquisitive type of mind, acutely aware of his ignorance in all fields of knowledge, including his own. He must value knowledge highly as a precious commodity in its own right and be willing to make large sacrifices in terms of personal comfort to forward his search for it. He must have a deep sense of the inherent rightness of the activity of investigation, regardless of where it may lead him; an abiding conviction that if he has devoted an entire lifetime to earnest and sincere inquiry, that life, regardless of the tangible gains that it may show, has been well spent. He must be acutely sensitive to both blame and praise in the matter of the sincerity and the effectiveness of his quest for knowledge, but relatively insensitive to praise or criticism in more worldly and less fundamental matters—a quality which may count for much under certain conditions of social stress. A sure sign of a potential permanently dissatisfied worker is a tendency on his part to give primary consideration, in selecting his field of effort, to its promise of lucrativeness, or to the likelihood that it will lead to quick fame. It is rarely indeed that either of these objectives can be readily achieved. When they come, they are usually unexpected and unbidden. The worker must be constitutionally independent in thought and action, but of sound judgment in conducting his research. Particularly if he works in a large industrial laboratory, he must be of sufficiently pleasing temperament and accommodating disposition to fit him to mingle easily with, though not necessarily to lead, fairly large groups of his fellow workers.

These qualities, which appear to be universally desirable among research workers, though by no means peculiar to that class, are all traits of character. They are essentially the traits of the creative artist, the outlook of the man whose primary standards are the internal ones of inherent achievement rather than the external ones of public reaction, appreciation, and recognition so essential to the administrator.

Intellectual Traits

Surprisingly enough, there does not appear to be the same uniformity in purely intellectual characteristics among first-class research workers that is found in traits of character, so that here it is much more difficult to speak in generalities. This situation arises in part from the extreme heterogeneity of intellectual processes included under the single term "research." The process of research differs widely, in intellectual terms, from one scientific field to another, and among different parts of any given field. Thus intuitive and coordinative faculties of a high order are required in research in a very new field, where little background knowledge is available and much guessing of a qualitative nature must be done; where broad theories must be erected for trial on the basis of relatively few facts. Such procedures require a capacity for generalization, a willingness to advance the theory much further than it is fully supported by fact, which is at wide variance with the primarily analytical powers and the highly critical attitudes demanded of a scientific mind working in older and better established areas.

Again, within a single field of research, there are vast differences in the types of thought required of the man who will point out, head, and develop a new region of theoretical research from which practical consequences of the highest importance may flow, and of the man who will spend many years in gathering the data, under close direction, which will substantiate the conclusions in that field. There is also considerable evidence that a particular type of mind may be inherently more capable in one area of subject matter than in another. There is room in the research profession for only one general type of character, mores, and motivation. There is room for many intellectual types, ranging from the nearly pure empiricist to the most hardened, the most highly critical, of skeptics. Furthermore, a judicious mixture of these various types is almost essential in any industrial laboratory, for every such organization will cover a wide range of work, not all of which can be agreeable to any one mental type of researcher.

Training

This diversity of intellectual types which may contribute valuably to progress in research makes the specification of any general training requirements for the research worker an extraordinarily difficult, if not an impossible, task. It may be said, on the whole, that an undergraduate collegiate education, in which the study of science has played a prominent role, is a *sine qua non* for the industrial research worker. There are, however, numerous examples, in many large industrial research laboratories throughout the nation, of highly successful workers who lacked this advantage when they entered upon their life work, but had the drive to attain it in their spare time thereafter.

Graduate Training

The desirability of a specialized education beyond the undergraduate collegiate grade is dependent both upon the kind of laboratory for which the worker is being selected and the position for which he is intended within the organization. If he is expected to develop into a group leader, or if he is sought as a pioneer worker within a given technical field, the extent of his formal education in the subject matter of the field where he will work becomes of great importance, since a wide background of knowledge is essential here. A doctor's degree in the general subject where his work will later fall may be a good guarantee of his general competence within that field. Equivalent industrial experience elsewhere, with a promising record, may give as good evidence of his background knowledge and research ability, and a discerning director may not be too much interested in his formal academic qualifications under these conditions.

The educational qualification of greatest importance in the potential research leader is a thorough grounding in the fundamentals of his field, a grasp of basic principles coupled with a broad vision and courage to make bold decisions in planning his work. It is far more important that this grounding shall have been thorough than that the worker shall have received a highly specialized but superficial training in the details of the particular problem that he is about to undertake.

If the man is sought primarily to fill a gap in an existing or a contemplated research team, or if it is expected that his primary work in the organization throughout his life will be the conduct of research under the intimate direction of others, the matter of his educational qualifications becomes of somewhat lesser importance, since much of the needed background will be furnished by his director. Men of this type, provided they have the research spirit, may, if necessary, acquire much of their particular background in the field which they are attacking as they proceed with it.

Before the war, the supply of young, formally trained scientists in the various fields of interest to industry was somewhat, and at times considerably, in excess of the demand. Under these conditions, it was natural that those with the most extensive formal training were at a premium in this market, and it was rare that the larger industrial laboratories considered adding to their permanent staffs any man who had not obtained a doctorate or its equivalent in experience.

Now in the immediate postwar years, when the supply of young, scientifically trained men has been depleted through the cessation of wartime training activities and through the drainage of much of the existing personnel into other fields, this situation has been reversed. Under present conditions, it appears that more attention is being paid to traits of quality and character and promise of development as informally determined, and less stress is placed, for the time at least, on formal academic qualifications.

Qualities of intellect and training lend themselves to an assessment from paper records somewhat more readily than do those of character and personality, although even here care must be taken not to rely upon them too fully, lest some otherwise outstanding men be lost. It is a good rule, however, that, other things being equal, the most highly trained research worker is the best bargain for any research director, regardless of the sort of position which he is destined to fill. It is virtually impossible for a creative worker of high training to remain for any period of time in a research laboratory organization, no matter how menial the position he may fill, without changing the character of that position and of the whole laboratory, to its inestimable benefit, if the atmosphere of the laboratory approaches what it should be. The working program of any laboratory is necessarily a highly flexible thing, built primarily about men. Any man of high qualifications carries forward the entire laboratory in his growth. It was a general realization of this situation which led to the tremendous demand for research workers holding doctors' degrees in their specialties before the war, when such men were easy to get. Such a "blanket" procedure may be much less feasible for many laboratories in the immediate postwar period.

In summary, then, we may state that the primary qualities of research workers are those of character: innate creativeness, a flair for and a deep belief in the processes of investigation and the worth of investigation as a career; curiosity; integrity; dependability; endurance. These can be recognized only through personal acquaintanceship of an indefinite duration, and can seldom be fully appreciated except by men who share the same characteristics. Qualifications of education can be more readily determined in a formal way, although they, too, require experience to prove them.

As a general rule, an education equivalent to the doctorate in the worker's special field is highly desirable, and, if he is expected to lead research, considerable post-doctorate work, of fellowship or other character, may be required. If he is to enter, and plans to remain in, a fairly subordinate role in the research team, however, these qualifications may, if necessary, be considerably abridged, for training equivalent to the doctorate, or even to a bachelor's degree, is not necessary to permit a good man to do good work under close direction. It must be remembered, however, that it is much better for a laboratory to acquire a man who is too good for the job to which he is first assigned than one who barely meets its requirements.

Accordingly, every effort should be made, consistent with the market demand, to obtain the best men possible from an educational standpoint, even if their positions, for the first year or so, may not be of standards equal to that training. It is of course imperative to remember, if this procedure is followed, that great flexibility of organization and plan must be retained within the laboratory to permit the man, after he has proved his qualifications in the initial period, to rise above his old job to whatever new levels his abilities may permit. For it is a human wrong, as well as an administrative error of the first water, to confine a man of high ability to a job of low caliber. Such a procedure should result, if it does not, in the speedy loss of the man and the deterioration of the laboratory in the eyes of those well-qualified, potential researchers who may think of making it their permanent working place.

The Research Atmosphere

The research process, like the research worker, is intensely individual as well as co-operative in nature. However closely knit the laboratory may be as a team, however well co-ordinated its program, it is essential that the basic conditions which it provides be those which will appeal and offer satisfaction to the individual creative thinker within it.

One of the most fundamental of these conditions is adequate security. Once the worker has proved his ability and fitness for his job, reasonable assurance of tenure should be given him, and adequate provision should be made for his future monetary security and that of his family. Once he has really dedicated himself to his work, it is likely to be a life commitment for him, and one that will leave him relatively little opportunity for self-betterment. If he is to be kept free from the sort of gnawing family worry which will destroy much of his creativeness, or if he is to be stopped from the much worse alternative of devoting only a portion of his energies to the job in hand while the rest is devoted to seeking for a supplementary or a better job, it is all-essential that clear provisions for security be made, and that these, and his reasonable future expectations in financial terms, be made clearly known to him. Inherent in this thinking for future security is the question of the final elimination of the man from the organization, when his abilities and interests may have contracted to a level which will make further association between the worker and the laboratory unprofitable from both sides. Larger industrial organizations, in the various cases which have been examined, vary in the means by which they meet this need between various types of pension plans and a high salary, during the creative period of the worker's life, to permit him to amass his own savings. The relative merits of the methods appear to vary with local conditions, but there is no question of the desirability of some method of meeting the condition.

Second perhaps only to security in assuring the happiness of the creative industrial research worker is a relatively large degree of individual freedom in prosecuting his job as he sees fit. It is not always easy to insure freedom of this kind in the conduct of highly competitive industrial research where the drive to regimentation may be very strong indeed. The worker, however, is essentially an artist, and, although he may or may not be possessed of an artist's temperament, the granting of as much freedom as possible, consistent with the efficient performance of his work, is almost certain to pay handsome dividends to both the worker and the laboratory. It is not always mechanically possible in large organizations to defer to certain minor idiosyncrasies of various individuals, which may nevertheless be very important to themselves, such as particular eccentricities of habit, a preference for irregular though long working hours, a tendency to work at high pressure for a period and then to relax for an interval of recovery, and so on. Wherever it is at all possible, however, to adjust organizational matters to permit these small irregularities, many good men who otherwise would be misfits can be made content.

Freedom of Work

A matter of peculiar importance in this connection is the attitude of the worker toward the particular problem assigned him. Few workers can really succeed in a problem which has not elicited their sincere interest. Accordingly, it is wise, whenever practicable, so to arrange matters that the worker has at least a modicum of freedom in selecting his own job. For example, the job assigned to him may be one of several possible alternatives among which he himself has made the choice. By the same token, it is important to avoid a practice which is all too common among industrial research laboratories—that of unnecessarily transferring a worker very frequently from one job to another before he has had an opportunity really to succeed in any of them. The undertaking of a given job requires a considerable period of orientation on the part of the worker, during which he must become thoroughly acquainted with the background literature of the field, must study the techniques involved, must set up and conduct preliminary experiments to determine the most promising avenue of approach. This requires a considerable expenditure of time and energy before productive work can begin. If the worker is repeatedly transferred from job to job just at the end of the time when he has gone through this preliminary schooling and before he has had the chance to become creative, he will soon become discouraged and disgusted. The quality of his work is likely to decline, for the truest incentives in it have been removed, and at the end of his active life the laboratory is likely to discover that it has been paying him for a lifetime of preliminary investigation, at high cost to itself. There is such a thing as professional as well as monetary security in a position, and the research director should make every effort to preserve it for his men. Finally, it is important wherever possible that the research workers be given the opportunity to try out ideas of their own, in an extracurricular fashion, as it were, for their own satisfaction. The definition of what constitutes extracurricular activity will vary from laboratory to laboratory. One of the best arrangements seems to be to permit the worker to use laboratory equipment and other facilities freely for work of this kind on his own time, providing such activities do not infringe upon the proper use of "company time." Some laboratories go further than this, and permit the worker to "play" with problems of this sort on regular working time when there may be a slack period in the prosecution of company problems. Provisions of this sort may well vary with the man, ranging between the extremes of the uncreative type, whose work must be highly directed and whose value to the company depends largely upon the mere mechanics of the operations which he conducts, to the highly trained and inspired individual whose own creative ideas largely determine the lines which the laboratory will follow in its official capacity. It would obviously be unwise to treat such divergent sorts of men in the same manner. Whatever the arrangements made, it is important that a clear-cut understanding be arrived at beforehand as to the distribution of proprietary rights between the worker and his company in any "nuggets," such as patentable inventions or new and potentially lucrative processes, which may be discovered as a result of this extracurricular activity. Many kinds of arrangements are of course possible, varying greatly in the distribution of rights which they effect between the individual and the company. The important thing is that one be definitely determined and clearly established before any such "nuggets" are uncovered. (See Chapter XII.)

Outside Contacts

Failure to encourage the research worker to take time from his job to make numerous professional contacts, both within his own laboratory as well as outside of it, constitutes a real administrative error. The utmost freedom of intercourse between laboratory workers is essential to the peak efficiency of operation of the organization. Far more can be lost than can ever be gained by screening one department of the research laboratory rigidly from another, unless special secrecy situations demand such screening, or by ignoring the self-evident precept that generalized scientific findings are almost always of use in more than one area of investigation. Contacts of this sort should not only be permitted, but very actively fostered, for few human tendencies are stronger than the inertia which keeps workers in adjacent rooms, or teams of workers in adjacent buildings, utter strangers to one another over the years. Outside the company, the worker should be actively encouraged to join professional societies, to attend scientific meetings, and to deliver papers, whenever justifiable, on scientific and policy grounds. In the case of small laboratories, the director should make a very special effort to see that the widest outside contacts are actively maintained, a matter

PHOTO. 15. Practically every scientist likes to have a certain amount of time to devote exclusively to his pet projects. *(Courtesy of the American Cyanamid Company.)*

which often presents special difficulties in the case of such small groups.

One way to achieve this is to encourage laboratory workers to attend university courses wherever possible. The establishment of co-operative relationships between industries and universities, whereby industrial workers may experience continuing university associations and training, is a subject which will demand much thought and attention in the future.

The holding of lectures and seminars within the laboratory, in which both laboratory workers and outside investigators may participate, is an unusually effective method of providing stimulation of this character. Such seminars, if given on a regular basis, will usually attract most of the laboratory staff and in time will also attract a considerable hearing from outside the laboratory group. In the case of larger research units, specialized internal seminars, held to discuss various aspects of particular laboratory problems, and to which outsiders are not usually admitted, may also be helpful. Above all, it is important that all personnel of the laboratory realize that there is ample scope for the expression of their ideas as they occur, and that these ideas will secure a careful hearing and sympathetic judgment from the laboratory management, and the results be made known to them.

At times outside contacts must be actively brought to the worker by the research director. It seems to be characteristic of the research temperament that, during peak periods of intensively concentrated effort—peaks which may last for a year, or more in rare cases—normally sociable, percipient individuals become extremely shy and retiring. The ability of any man to make contacts freely and graciously is likely to be seriously curtailed during such periods of severe mental application, and his laboratory and director should protect and aid him during such times.

Material Factors

Paramountly important as are the intangible elements in the laboratory atmosphere in assuring the success of its research, various material factors also contribute an important, though perhaps a secondary, part to the same end. Good laboratory facilities, good and sufficient equipment, good lighting and ventilation, adequate floor space, and provision for ready communication between individuals at no great effort stand high on the list. A fairly extensive library is a tremendous asset to any type of laboratory. In certain fields it is absolutely necessary, and workers should be encouraged to spend much of their time there. In some industries, extensive patent files, catalogued for ready reference, constitute a well-nigh indispensable part of laboratory equipment. The provision of central and decentralized machine shops, woodworking shops, and glass-blowing shops are of course also desiderata which are more essential in some types of laboratories than others.

These are some of the elements which must be considered by the research director in selecting the personnel which will compose his laboratory and in providing them with the spiritual and the material atmosphere in which they and their work will flourish best. Upon the skill with which he does this will depend a large measure of the success of the entire research effort over which he presides and for which he is responsible to his organization.

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CHAPTER XI

Qualifications, Training, Aptitudes and Attitudes of Industrial Research Personnel

In recent times much has been said about how the employer should treat his employees, and this has included lengthy discussions of how the research director should treat the research workers. It has been pointed out—not without justification—that in order to turn out first-class research work the scientist must have just the right tools, the right incentive, a conducive environment, etc. In this chapter an attempt will be made to discuss how the research workers should treat the research director. It is hoped that there will be no objection to this strange and apparently unwarranted procedure, for after all the research director is also human and perhaps worthy of some consideration. More important, he is most solicitous of his fellow employees' welfare and success, if for no other reason than the very selfish one that his success, more than that of a person in any other walk of life, is dependent on the success of his helpers. If they succeed in pulling rabbits out of the hat at the proper moment, he is a hero. But let the trick fail to come off and he is just another of those would-be inventors—wasters of the company's money which might better have been paid out in dividends to the stockholders.

There is no other single subject in the world of more importance to the research director than the qualifications, training, aptitudes, and attitudes of his personnel. It is one to which he must devote much attention, in the selection and placement of his people, if he

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is to hope to achieve the desired results. Effective personnel can overcome much in the way of lack of money or facilities, but no amount of money or facilities, no matter how excellent, can overcome the handicap of inadequate quality of personnel. Research today is dependent largely on teamwork, and the performance of the team as a whole is dependent on the proficiency of each member. It is equally important, therefore, that each worker, as well as the research director, understand the part he is to play and the needed qualifications, and that he try to attain them.

Broadly speaking, a person's characteristics may be divided into two main classes—the inborn ones which are inherited, and the acquired ones which come from training and practice. While such a classification is a convenient one, it is not a hard and fast one, as no really sharp line can be drawn between the two. Some characteristics, generally considered to be inborn, can be acquired, at least to a degree, although the process is generally a difficult one; further, some that are native can become lost. In this discussion, however, this general classification will be used and overlapping noted whenever it seems important to do so. Training, of course, may consist of formal training, as obtained in the schools and colleges, or that gained from experience.

School Days

To discuss formal college or university training in any detail is beyond the scope of this chapter. Emphasis will be placed, therefore, on a few highlights which seem particularly important.

Obviously, in preparing for any given work in life, the training should be made to fit the requirements. This is true of training for industrial research. Since the kind of research carried on in different industries varies both as to subject matter and method, and since in any single industry—in fact, in any given laboratory—each job may have its peculiarities, many of the situations encountered can scarcely be foreseen. A worker may find it necessary to adjust himself quickly to changing conditions. Therefore, while specialization to a degree is necessary, as much flexibility as possible is also desirable.

Two broad classifications of the types of jobs ordinarily carried on by technically trained personnel in industrial research laboratories are true research and technical service. The latter may consist of various kinds of more or less routine work carried on as a service to a factory, a sales department, or the true research workers. It might take the form of chemical analysis, physical testing, library or patent work. The work of a research assistant might also be so classified, as well as some kinds of engineering work commonly associated with research. For this type of job, four years of formal college training leading to the bachelor's degree generally is adequate. For true research—requiring independent scientific investigation and creative thinking—graduate training preferably up to the doctor's degree is highly desirable, often absolutely necessary. The main reason for this is that the chief purpose of such graduate training is to teach the student *how to do research*. Research may be divided into fundamental and applied, but in the general training needed the differences are not great. These two types of research differ mainly in objectives, rather than in method of attack, and whether a person is suited best to one or the other may depend more on temperament than training.

The question often asked by young men as to whether or not they should take graduate work can be answered intelligently only after a decision has been made as to the type of career chosen. If the career is to be true scientific research, either academic or industrial, it now seems to be pretty well agreed that graduate training is highly desirable, if not absolutely necessary. Almost invariably men who come into industrial research laboratories equipped only with the general run of four-year training do not succeed in doing effective research work until they have had several years of experience. To put it another way, it would seem that as a training for research, three years spent in graduate work in the university is worth more than the same time spent in getting industrial experience. The reason for this is, of course, that the three years in the university is concentrated training, while that in industry is diluted, because of the need for carrying on other tasks, many of them routine, at the same time. In the university, all the effort can be put on the job of learning *how to do research*, while in industry most of it has to be put on the doing of other jobs.

This is not to say that there are not many jobs in the industrial research laboratory which can be done satisfactorily by four-year men. It is not to say, even, that such men cannot succeed in doing research—a great many have. Generally, they are as well equipped to rise to administrative positions as those with graduate training. Nor is it to say that a doctor's degree is any guarantee of success in research. Graduate training is valuable added equipment, but it does not guarantee success in research or any other field.

Education, furthermore, may consist of two main types: the learning of facts and prescribed methods, and the learning of how to use principles. The former requires mainly a good memory, while the latter requires good reasoning power. If, as a layman in relation to the professional educator, the author may presume to offer a criticism of our college training, it would be that frequently too much emphasis is placed on the learning of detailed facts and routine methods, and not enough on the thorough absorption of the fundamental principles of science. Given the latter, a person often can work out or look up the former, but lacking it, he may scarcely know how to use the former, no matter how well he has learned the facts. Important also is the fact that one who is well grounded in the fundamentals generally will be able to adapt himself more quickly to changing and unexpected conditions. Such versatility is extremely valuable to the industrial research worker.

If another criticism may be offered, it would be that often too much stress is laid on examinations, and not enough on the retention of what has been learned for a reasonable length of time after the examination is over. As a result, many a graduate from a highly accredited college comes to industry literally in complete ignorance of facts and principles, which we know full well he must have been taught by his fond alma mater. Some system of continuous review, which would improve this state of things, ought to be worth trying. A few things well learned and retained would seem to be worth more than a lot of undigested learning soon forgotten.

W. J. King, in a series of articles on "The Unwritten Laws of Engineering,"[4] discusses certain principles concerning general behavior, attitude, and relations with others. These articles put the spotlight on another apparent fault in our system of formal education of engineers and scientists; namely, that scientific schools quite generally neglect to teach the student how to handle himself and work in harmony with others. This is perhaps more true of science and engineering courses than of those in the arts. In the anxiety to impart knowledge of the physical sciences, the science of human relations is neglected, but later in life it often becomes as important to the worker in industry as his knowledge of the physical sciences.

Live and Learn

So much for the formal training which ends with the presentation of the diploma on the happy commencement day. "Commencement" is indeed the word, for, while it marks the end of the period of formal training, it should be the beginning of a longer period of learning extending throughout life. Someone has said that, if one can keep on studying and absorbing new knowledge until after the age of forty, he is very apt to continue to learn new things and grow in knowledge for the rest of his life, but that if one stops learning before the age of forty, it probably will become very difficult for him later to resume effectively the acquisition of knowledge on any important scale. Perhaps it might be said that "life begins at forty" for those who have not already become mentally dead before that age.

It would seem next to impossible for anyone to become mentally stagnant in the atmosphere of a modern industrial research laboratory. Strange things, however, can happen and occasionally one will find an individual some years out of the university who, to all intents and purposes, has not learned one living thing since the day he stepped off the platform with his diploma in his hand. And there can be found plenty of men who, at the age of fifty, are still drawing on the same intellectual reservoir they had at age thirty-five. Furthermore, these will have no more resources at sixty. All development had ceased apparently somewhere between thirty and thirty-five. Contrary to common belief, senility does not necessarily wait to set in until age sixty-five. It may start at twenty-five.

Such a sad state of affairs is entirely unnecessary. All have known men of advanced age who were just as keen of mind and as interested in new things and new ideas as they were in their twenties. They learned something new and useful just yesterday. Their reservoirs of knowledge are still filling up and will continue to do so. Men are frequently known to do the best work of their lives after the age of sixty. Two striking public examples of this in the late war were in the persons of Douglas MacArthur and Winston Churchill. Probably no one can say, with any degree of certainty, how these men were able to accomplish such feats, but it was probably because they had never stopped filling their mental reservoirs, with the result that when the critical hour came they had plenty to draw on, from minds made vigorously active through continuous exercise.

So the writer cannot urge too strongly that every effort be made to keep on learning. One should take advantage of every opportunity to pursue in spare time some course of regular study. If one cannot take some prescribed college extension course, then at least one should try to lay out for oneself some systematic plan of home study. The subjects pursued might better be somewhat different from those encountered in regular daily work, to avoid getting the mind into a rut.

In following this advice, however, a man must not overlook the importance of learning, above all things, all there is to know about the job on which he is working, and anything in any way related to it. It is particularly important to know what the duties are and what is expected in the way of tangible results. When men fail, it is often because they simply do not know what is expected of them. This, no doubt, is just as much, if not more, the fault of the management as of the personnel. But this does not help when it is too late. Hence the importance of finding out all about the job and its requirements. One should make sure that one is thoroughly familiar with all the technology needed, and if not, do something about it.

Another important thing for the worker to know about his job is where it is taking him. If he is to make progress, his present job should be considered in the light of a stepping stone to a different and better one. So he should try to figure out what this different and better job might be and start preparing for it. He may never get it. His next job may be something totally unexpected, in spite of his best guessing. Nevertheless, the exercise of the preparations he has made will have benefited him. Looking ahead and preparing for the future is seldom a total loss. Some plans, even if they do not work out as hoped, are always better than none.

Finally, a man should try to learn all he can about the company for which he is working—try to find out about the products it sells, its policies, and how it is organized. Such information will help him better to understand how he and the particular group in which he is working fit into the whole picture. If it is a good company, intimacy with its workings will serve to increase his loyalty to it.

As Others See Us

What has been said up to this point has had to do mainly with the technical training and other learning, formal and informal, which should be acquired in order properly to qualify personnel for industrial research or the allied services. The other phase of this subject concerns those native personal characteristics which are believed to be essential to the scientist. In fact, a considerable portion of this chapter will be devoted to this phase because of the important bearing it is thought to have on success or failure.

The personal characteristics to be discussed do not necessarily have to do with ability to learn and practice science. Much has been heard about scientific talent or scientific aptitude. Naturally, it is hopeless for a person deficient in aptitude for science to embark on a career in industrial research. We pass up this point, however, because it already is being well taken care of by the colleges and universities. First, these institutions for the most part have adopted systems of vocational guidance, which tend to weed out the inept at the outset. Secondly, the college course itself is a pretty good screen which further eliminates those devoid of talent. It is quite certain, therefore, that by the time students have completed their four years—certainly by the time they have their doctors' degrees—the fact will be pretty well established that, despite differences between individuals, each has enough science talent, or aptitude, to do any scientific work likely to be required of him in the field for which he has prepared. Personality traits are a quite different matter. Out of the author's contacts in more than thirty years in industrial research, he can recall scarcely any people who have failed because of inadequate scientific aptitude or training, but he has known quite a few who have fallen by the wayside because of some unsatisfactory personal trait or attitude of the sort to be examined.

Madame Chiang Kai-shek spoke on the radio the evening the news came of the Japanese surrender. Her talk was very brief but very much to the point and illustrates the item being discussed. Her statement was to the effect that what is wrong with the world is that we have allowed our progress in material things to get too far ahead of our progress in spiritual matters. There is an analogy here to what was said earlier in reference to W. J. King's articles on the "Unwritten Laws of Engineering," namely, that in our anxiety to teach more science better we have neglected to develop those personal characteristics which are even more necessary. This subject is also very ably dealt with by A. W. Hull.[3]

The ancients taught that seven is the perfect number. It is the author's belief that there are seven major traits of personality which, if combined in an individual in the right proportions, will make for perfection and lead to a successful career. These are: aggressiveness, creative imagination, judgment and sense of balance, accuracy and capacity for detail, leadership and organizing ability, co-operativeness, and optimism. The required proportions will vary somewhat for different walks of life. It may seem surprising that some of these are essential at all in industrial research, but the discussion which follows will show why they are. If enough were known about the subject and we were sure of the exact proportions, it might be possible to express the whole thing as a mathematical formula. Since this unfortunately is not the case, it is necessary to fall back on statements of experience, which may appear to be rather vague generalities.

Doers

Webster's dictionary defines aggressiveness as "disposition to attack or encroach, self-assertiveness, pushing, enterprising." The word has fallen somewhat into disrepute because of its association with *aggressor*. In this sense it deserves its bad reputation. It is, in fact, a desirable characteristic only when tempered by good intentions, good judgment, and common sense. Otherwise it may be more of a curse than a blessing. It is the motive power that makes for action—makes the individual a self-starter. There is the saying: "Action without direction is simply a faster form of drifting." This is all too true and will be emphasized later. But, on the other hand, without action there can be no results. Aggressiveness not only starts the action, but goes on to overcome obstacles and push the enterprise to a conclusion. There are two kinds of people: those who get things done and those who spend about the same amount of time thinking up reasons why things should not be done. The aggressive ones are of the former kind. The aggressive person does not become easily discouraged, does not give up easily.

The all-absorbing interest of the aggressive individual is to get the job done. In his anxiety to do this he sometimes may cut across orthodox organizational lines and cause friction. This generally is bad, but occasionally may be justified by the results obtained. Also, the aggressive person will look for things to do beyond what he is told, and in doing so he may sometimes get "off base" and do more harm than good. If, however, his intentions are good and indicate a truly enterprising spirit—not just an attempt to show off—his indiscretion may be rightfully overlooked. Here again the proper tempering with sound judgment is what is needed.

The aggressive soul is not only willing but eager to take on responsibility. The timid soul avoids responsibility. He figures "Nothing risked, nothing lost." The bolder type feels "Nothing ventured, nothing gained." The difference in philosophy is quite striking. The biblical parable of the talents is a perfect illustration.

Aggressiveness springs from conviction. Most people cannot be aggressive about something in which they do not believe. Maybe the professional politician can be aggressive about a thing regardless of his convictions. Anything to get out the vote. But a person with the intellectual honesty needed to do good research work must really believe in a thing in order to become enthusiastic about it. Therefore, if he does not thoroughly believe in what he is doing he should either convince himself by honest reasoning or get to doing something different as soon as he can. An honest confession will do him good, and his boss—if he is the right sort—will thank him.

Aggressiveness springs also from good health. If one does not feel well his enthusiasm is bound to be at a low ebb. Vigorous health is a gift. It seldom can be bought. If one has it he should be grateful and do everything possible to preserve it.

These notes on aggressiveness would not be complete without a word on salesmanship and its place in industrial research. Many research men feel that salesmanship has no place in research. Research to them is a cold, impersonal affair. Salesmanship savors too much of wishful thinking, is beneath the dignity of the scientific man. Be this as it may, many a high-grade research man has never emerged from obscurity, merely because he never learned how to "sell his stuff." And believe it or not, it does have to be sold. The fruits of research are of no earthly use until someone gets them out of the laboratory. And getting them out of the laboratory and into commercial use is often more difficult than discovering them in the first place. The management that holds the purse strings and determines the policies of the company has to be convinced that the findings of the laboratory are worth exploiting, and usually none are in a better position to do the convincing than the men who did the work and, therefore, ought to be the most enthusiastic about it. If they do not believe in it enough to do some talking about it, how can others be expected to? The sooner one learns to appreciate this fact the better. Of course, this sort of thing can be overdone. Just making a pest of oneself is not good salesmanship. And one should be sure that what he is trying to sell is sound. A scientist promoting an unsound project is soon discredited not only in the eyes of his associates but also in the eyes of those he is trying to sell. The salesmanship of the research man should spring from sincere enthusiasm for a good job well done.

Dreamers

In the jargon of the United States Patent Office, an invention takes place in two steps: the conception of the idea and its reduction to practice. A thing must first exist in the imagination before it can even be tried in the laboratory. This is what we mean by creative imagination. Webster defines the word *invent* as meaning: "to fabricate mentally, create or devise in the imagination." It is necessary to distinguish between invention and the mere application of technical skill. Many a patent battle has been fought around this distinction. Invention goes beyond the ordinary predictions of technical skill. An engineer who uses his technical knowledge to build a bridge is not the inventor of a bridge. He cannot get a patent on it. But if the bridge contains in its construction some element never heretofore used, the concept of which is outside usual practice, this particular element may constitute invention.

The American Society of Mechanical Engineers published in July 1944 a series of articles entitled collectively *Creative Engineering.*[2] These articles try to define inventive ability and to explore the principles underlying it. They attempt to indicate the process of inventing and how inventive talents may be cultivated. Everyone is born with a certain amount of inventive instinct which later will be sharpened or blunted by training and environment.

Scientific training will not make an inventor. In fact, it may be a hindrance. In *Creative Engineering,* Mr. C. F. Kettering says:

> Some years ago a survey was made in which it was shown that if a person had an engineering or scientific education, the probability of

> his making an invention was only about half as great as if he did not have that specialized training. Now that is very interesting, and I have spent a great deal of time wondering why it is so. As a result, I have arrived at a definition of what an inventor is. An inventor is simply a fellow who doesn't take his education too seriously.

What Mr. Kettering is driving at here, of course, is that the free play of the imagination can be readily throttled by a knowledge of too many facts—facts which incessantly are pointing out reasons why something cannot be done. This is not to say that scientific training is intrinsically detrimental. It is bad only when it dominates thinking and hinders free play of the imagination. It should be the guide, not the master.

The highest type of creative imagination is inclined to ignore facts such as those which comprise the formal body of knowledge, and to depend more on intuition than reason. Creative imagination means thinking beyond knowledge. There are many examples of the wildest imaginings of fiction writers eventually being realized at some later time. An astonishing percentage of the things described in the stories of Jules Verne—things which seemed fantastic at the time he wrote them—have since come to pass. Igor Sikorsky in the same *Creative Engineering* series says:

> I believe that in the field of science many important discoveries have been made with the assistance of intuitive apprehension. Great men like Aristarchus of Samos, Archimedes, Newton, and several others upon many occasions created correct theories or made true discoveries long before enough tangible evidence had become available to justify their assumptions.

While Mr. Sikorsky's statement at first may seem startling, many will be inclined to agree after thinking it over. Many of the daydreams of childhood are realized in later life. Many of the things which are instinctively felt to be so may be just as true as the things that can be proved.

The prophets all seem to have had visions. The inventor in a sense is a prophet, in that he is able to foresee heretofore unconceived products and processes. Nearly all people have some of the instincts requisite to creative imagination. Insofar as this is the case, they should be cultivated. It pays to relax and dream once in a while. It is in these periods of relaxation that ideas most often come, rather than in times of stress and anxiety.

This does not mean that life should be just one long period of relaxation and daydreaming. Visions are of no value unless they are followed up with some sort of action. The ideas must be reduced to practice. Something must be done about them. And one should not let ridicule stop him. Most good ideas have been laughed at at some time. Here is where a combination of aggressiveness and vision is needed. It is a combination hard to down—particularly if there is added to it the characteristic which is to be examined next, namely, judgment and sense of balance.

Sages

The trait which is being called "judgment and sense of balance" is the flywheel or governor which controls the enthusiasm of the doer and the dreamer and helps to keep him "on the beam." A colloquial description would be a person with his feet on the ground.

A possessor of this characteristic will keep things in proper perspective at all times. He will see all sides of a question and never let his enthusiasm warp his judgment. He will suspend judgment until all needed data are before him, and then will properly weigh the various factors before making a decision. He will be able to consider the broad aspects of a situation and not be confused by a mass of detail.

He will have a good sense of proportion. He will know how to analyze a situation, sort out the pertinent data, and arrive at a sound conclusion. He will have the ability to distinguish the essential from the nonessential. He then will have the courage to rely on his carefully considered conclusions without appearing egotistical or stubborn, and he will be able to inspire in others confidence in his judgment.

He will be able to maintain his composure in spite of heavy pressure or adverse circumstances. Many a person can think clearly and make sound decisions when time is not an important factor and the stakes are not large. But let the "heat" be on and the responsibility heavy, and he becomes hopelessly rattled. Coolness under pressure may be impossible to cultivate by all temperaments but it is certainly worth trying.

This is the characteristic which makes one a "good businessman," that is, a man with a good sense of commercial values. Industrial research has become a business; and there is probably not any in which a sense of commercial values is more important. Chasing rainbows is just as fatal in industrial research as in any other business. Of course, it must be recognized that in research it is impossible to foresee the outcome completely. If the outcome were known it would not be research. It is, however, perfectly possible to use horse sense. There are a few things which can be figured out in advance with reasonable certainty. A pretty good guess can be made as to whether or not the problem on which work is being done is worth solving. About how much money its solution warrants can even be determined with some fair degree of accuracy. The probability of a successful outcome can also be gauged with some accuracy, but this is not so easy. Again, if this could be done very well it would not be research. At any rate the best attempt should be made to try to answer these and other questions. Someone will say, "But this is the job of management; I just work here." He is wrong. The sooner he gets this straight the better. He, as a research man, *is* part of management. He is hired to use his head to think commercially as well as technically. Furthermore, there is no one quite as close to what he is doing, no one quite as well able to judge of many things about that specific job as he. Earlier it was said that the research director needs his employees' help. He needs it in making these all-important commercial decisions.

Sound judgment is mainly a manner of forming the habit of sound and careful thinking. It certainly can be cultivated to a degree. One should examine himself. Anyone with a better than average I.Q. should be able to determine whether or not the decisions he has been making have been good ones. If he finds that his decisions have not been so good, perhaps it is because he has been jumping at conclusions. If so, he should think twice next time. Often it is an excellent idea to "sleep on it." Things look different in the morning from the way they looked the night before. Cultivation of this characteristic is helped by learning to take pains, which is the subject to be examined next.

Painstakers

In the immortal words of Winston Churchill: "I bring you sweat, blood and tears." The characteristics of accuracy and capacity for detail spring from the same basic trait, namely, willingness to take infinite pains and, if necessary, to work long, hard hours to do it.

No matter how much enthusiasm, or creative imagination, or even good judgment a man may have, he will accomplish little unless he is ready to make the sacrifice of doing the hard work necessary in getting together the facts required for making decisions, planning next steps, etc. In other words, he must be prepared to furnish the necessary perspiration to accompany the inspiration.

Capacity for detail varies greatly in different individuals. Some people have a mania for it. All are familiar with the person who just loves to collect statistics. He collects them as another might collect postage stamps or coins. He is always telling about them to the amazement of all concerned. But very often he has not the vaguest idea of how to put all his information to work. The value of this trait may be lost, therefore, if a person of this type happens to be put on the wrong kind of job, or has no supervisor to guide his thinking in the right channels and to make use of the data collected. He may become just a walking encyclopedia, which will produce nothing at all.

This capacity, however, is extremely valuable when accompanied by a proper proportion of the other traits being discussed. Effective work cannot be done or right decisions be made without having the necessary data at hand. Often the collection of this information is an arduous task requiring great patience and perseverance. The person needing these facts must either get them himself or have someone do it for him. When frequently the latter is not possible, the effectiveness of the individual is restricted greatly, if he cannot or will not get the information for himself. In the early years of his career, a man usually has to do much of this sort of thing, and it is a good time to cultivate whatever capacity he has.

Accuracy is being considered along with capacity for detail, because it almost always accompanies this trait. A person who is able and willing to collect facts is usually equally concerned about their accuracy. He will take pains to be sure of his sources and measurements. All of this includes, of course, data obtained from experimental laboratory work as well as from books, reports, and other literature. It is essential, therefore, that he have the ability to do accurate and painstaking work in the laboratory. The importance of this can hardly be overemphasized.

There are several other attributes of this general characteristic which should be mentioned briefly.

One of the most important of these is what is often called intellectual honesty. This means, first, being honest with oneself. This is believed to be an attribute of accuracy and capacity for detail, because a person of this stamp naturally will seek to base all his opinions on solid facts. He will not "kid himself." He will not allow himself to be influenced by "wishful thinking." And if he will not deceive himself, it is unlikely that he will try to deceive others. This discussion is not about downright dishonesty and crookedness. A person who would never tell a deliberate lie may nevertheless present facts in a misleading manner. Then, too, it is possible to tell only half-truths. This is an extremely important matter which may well mean the making or breaking of a man's career in industrial research. The scientist who allows himself to fall into the habit of presenting data in a distorted manner in order to stimulate or discourage interest in a given project is doing himself and his whole profession a grave injustice. Regrettably, however, it is done all too often. To repeat, generally it is not deliberate dishonesty. It is merely that a man so earnestly wants a thing to be so that he disregards, even in his own mind, all unfavorable evidence. An accurate person with sufficient capacity for detail will not make a report until he has all the facts, and then he will present them exactly as they are, without coloring.

Another attribute of this trait is that a person of this type will be neat, orderly, and safe in his work—a "good housekeeper." Perhaps those who have not been in industry long do not know what is meant by a good housekeeper. In any well-run industrial laboratory, it is considered worth while to keep the place clean and orderly, and this is everyone's job, not just that of the janitor. It has been observed that people who are orderly in their minds are apt to be orderly in other ways. This mental orderliness is probably also generally reflected in orderliness and neatness of dress and personal appearance. This no doubt explains why, when a candidate is interviewed for a job, his personal appearance is instinctively noticed. It is quite likely to be an indication of whether or not he will think and work in an orderly manner.

What is believed to be a secondary result of this trait is the ability to express oneself clearly either in speech or writing. If one expects to be clearly understood, one must first be sure that he is thinking clearly. Fuzzy thinking cannot help but lead to fuzzy talking and writing. Conversely, one who thinks accurately, who carefully classifies and organizes his thinking, is quite likely to express himself clearly. The importance of this should not need further emphasis.

Leaders

The next personal characteristic on the list is leadership and organizing ability. It is perfectly possible for a man to do excellent research work—all by himself or even with one or two minor assistants—without having any of the qualities of a leader. If, however, he is ever to advance to a position of greater responsibility, it is essential that he possess these qualities at least to some degree. If he is ever to direct successfully a large group, he should have these qualities in a fairly large degree. What, then, might some of these qualities be?

First, he needs those personal characteristics which have already been mentioned—particularly aggressiveness and good judgment. Aggressiveness implies enthusiasm and, if he is to instill enthusiasm in others, he first must have it himself. A leader who is not thoroughly "sold" on the project on which his group is working can hardly inspire loyalty for it in others. Of course, it goes pretty much without saying that if his judgment is not sufficiently good for him to make sound decisions with reasonable consistency, he is not cut out for a leader.

Also of first importance is his ability to inspire in those under him complete confidence in his fairmindedness and spirit of fair play. Let him show any sign of playing favorites or looking out for his own interests at the expense of those of his subordinates, and he soon will lose the loyalty he might otherwise be able to command. Any kind of trickery definitely does not pay. He may be sure that he will be found out sooner or later. Subordinates are usually very quick to discover such things. He who is trying to lead others should continuously examine himself to make sure that his mind is open and ever prepared to meet his personnel problems fairly and squarely. It is also desirable to have a likable personality, but this is not so important as a reputation for fair dealing.

A good leader will also have the knack of improving the effectiveness of his people. Some leaders have this to a high degree. They somehow seem to be able to bring out the very best in those working under them. It is hard to explain how they do it. Perhaps one reason may be that they expect the best—not the worst—and that while they freely point out instances of poor performance, they are able to do it in such a way as not to be discouraging, but on the contrary to promote better work. Of course, a good thing is to be sure to give each subordinate all the responsibility he can handle, so as to keep him continually on the alert. Then too, praise will often accomplish more than censure, and should be given freely when deserved. The good leader must, of course, be firm, forceful, and decisive when occasion demands.

It also is important for a leader to be a good judge of people. They are not all alike and some will respond to one kind of handling and some to another. Then, if he is to delegate responsibilities wisely, he must understand thoroughly the abilities and limitations of each of his subordinates.

Co-operativeness must be mentioned here in connection with leadership, since it is highly essential that a leader be on good terms with the leaders of other groups with whom he is associated. A leader who is continually quarreling with his associates, and passing the buck all around whenever occasion offers, is on the road to failure.

Similarly, he must be on good terms with his superiors, not only in fact but in outward appearance. If he does not show loyalty to his boss, there is danger that his subordinates will not remain loyal to him. This does not mean that he must be a "yes" man, who never disagrees with his superior, although it is better not to do so in the presence of his subordinates.

Finally, he must be capable of organizing his job, getting it done efficiently, and bringing his projects to successful conclusions. Not only is this important from the standpoint of his responsibility to the management, but also from that of his relations with his subordinates. No one wants to be on a losing team. If the enterprises with which he and his group are concerned are consistently getting nowhere, he soon will lose prestige with both his boss and his people.

Ball Players

W. J. King, in the series of articles on "The Unwritten Laws of Engineering," referred to earlier, goes thoroughly into co-operation and its value not only to the organization but also to the people in the organization.

A perfectly smooth working organization is the dream of every research director. Not only is this smooth working important within the organization, but also between it and the other units with which it must work hand in hand, if its efforts are to bear fruits.

In order to attain good co-operation in a group, it is first necessary to teach its principles and benefits to each member of the group until co-operation becomes a habit. The important thing to learn is that each person in the organization, in effect, is trying to do the same thing, namely, to promote the general interest of the company as a whole. Lack of co-operation usually springs from a concept in the minds of the members of a small group, or in the mind of a single person, that what they are doing is a very special job, in no way related to the job of any other group or person. They proceed to fence themselves in and put up "Keep Out" signs. Next, group B, observing the action of group A, decides to become exclusive too, since it seems to be the fashion. So the idea spreads, until finally the organization is nicely partitioned off into sections, each of which refuses to have much of anything to do with the others. Then come the rivalries, bickerings, and mud slingings between groups when things as a whole are not going well and each group contends that the fault must lie with some or all of the others. This sort of thing not only kills off the research director, but usually also affects a lot of other people farther down the line. One should fight it wherever it appears. Each individual should remember that such factionalism gets going because he, or someone like him, forgets the broader interests of the whole in a selfish desire to play the lone wolf. A similar situation can develop (with perhaps even more disastrous results) between the research organization and other units such as production or sales. While these things may be mainly the concern of management, it should be remembered that in the last analysis it is the contacts between individuals that make up the whole effect. Consequently, contacts must always be on a friendly and helpful basis.

Co-operation has become more and more necessary as industrial research has become more and more a teamwork job. All who have read the reports of the history of the development of the atomic bomb have no doubt been greatly impressed with the brand of teamwork which was brought into play. Here were a considerable number of independent groups, specialized in different fields, and each doing a very special task, but all carefully co-ordinated and directed toward the same common end. Although probably it did not all work out as smoothly as it seems in reading the history now, it must have been an unusually smooth-working machine to have accomplished this amazing feat in such a short time.

Another thing which disrupts the smooth operation of the co-operative machinery is the selfish inclination of men to want to work on their own ideas to the exclusion of the ideas of anyone else. This is a narrow and unreasonable point of view, which indicates absolute failure to grasp the elements of co-operative teamwork. If each member of the footbafll team should decide to follow his own idea of the best play to use, in utter disregard of the signals of the quarterback, the result is easy to imagine. The results of similar action on the part of the members of a research team should not be more difficult to picture. The American sporting instincts ought to furnish all that is needed to crack this problem, but apparently this is not always the case. Some people are rugged individualists to the last ditch.

Optimists

The last of the seven characteristics on the list is optimism, and for the research man it is perhaps about the most important one of the seven.

The biblical exhortation, "Seek and ye shall find," is more likely to turn out to be literally true if the seeker really expects to find what he is looking for, than if he is very dubious or entirely incredulous about the whole thing. This is quite true, although there do not seem to be any very scientific reasons for it. Maybe it is because he is more on the alert, his mind more receptive.

It should be noted further that the equation does not say that the seeker will find exactly what he is looking for, although it would seem to imply that it will be something desirable. Likewise the research worker very often does not find exactly the thing he seeks, but sometimes what he does find may be just as good or even better. Now looking at it in that light, it will be agreed that if he expects to find something good—even though it may not be what he started out after—then his chances are definitely better than if he expects nothing. In this case, certainly the alertness and openness of mind generated by the optimistic point of view will be helpful.

Another point in favor of the person with the optimistic outlook is that he is more likely to recognize a good thing when he sees it. There is good all around all the time, but unless the mind is in a receptive mood one often fails to see it.

Another reason why the optimist is more likely to succeed in research than the pessimist is that he will be more apt to keep up his courage. Research often can be very discouraging, and if the worker is of a pessimistic turn of mind in the beginning, as time goes on he may get into a very depressed state, such that his outlook becomes utterly hopeless. Research requires courage and perseverance. An inherently optimistic point of view is quite essential.

The point should not be misunderstood. The author is not advocating a foolish optimism, which ignores all the adverse factors. Such factors must be faced. It is necessary to see the hole in the doughnut. It is, however, even more important to see the doughnut. Blind optimism is bad, but so is blind pessimism. Neither is desirable, but if there must be one extreme, blind optimism is preferable—at least for the research worker.

Optimism is another word for faith. It is highly essential that the research worker have faith in the ultimate success of the project on which he is working. He need not believe that it will all work out exactly as planned. He will have a more open mind if he does not. He must, however, have absolute faith in its worth, and believe that something good will come out of it. The day he loses this faith, he had better say so and ask for another assignment.

There is much evidence indicating that the best creative research is done by relatively young men and perhaps the main reason for this is that young men inherently have a more optimistic point of view than older men. They have not yet encountered so many of the disillusionments of life. They still believe that something good is just around the corner. It seems, therefore, highly important for one following a research career to try to determine how best to retain this outlook on life as long as possible; in other words, how to stay young. Earlier mention was made of this characteristic of Douglas MacArthur, and after recording these thoughts the writer was interested to find an item in the January 1946 issue of *Reader's Digest*[1] which perhaps discloses the secret. It is an excerpt from a framed message entitled "How to Stay Young," which is said to hang over the General's desk wherever he goes. The *Digest* excerpt is as follows:

> Youth is not a time of life—it is a state of mind; it is a temper of the will, a quality of the imagination, a vigor of the emotions, a predominance of courage over timidity, of the appetite for adventure over love of ease.
>
> Nobody grows old by merely living a number of years; people grow old only by deserting their ideals. Years wrinkle the skin, but to give up enthusiasm wrinkles the soul. Worry, doubt, self-distrust, fear and despair—these are the long, long years that bow the head and turn the growing spirit back to dust.
>
> Whether seventy or sixteen, there is in every being's heart the love of wonder, the sweet amazement at the stars and the starlike things and thoughts, the undaunted challenge of events, the unfailing childlike appetite for what next, and the joy and the game of life.
>
> You are as young as your faith, as old as your doubt; as young as your self-confidence, as old as your fear, as young as your hope, as old as your despair.
>
> So long as your heart receives messages of beauty, cheer, courage, grandeur, and power from the earth, from man and from the Infinite, so long you are young.
>
> When the wires are all down and all the central place of your heart is covered with the snows of pessimism and the ice of cynicism, then you are grown old indeed and may God have mercy on your soul.

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CHAPTER XII

Procurement and Selection of Research Personnel

General

It is widely recognized by those experienced in the management of research that the procurement and wise selection of research personnel is one of the most important functions in the development and operation of research laboratories. Success in research is assured by wise selection and proper direction of the research workers. Since the competitive nature of selection and procurement of research personnel reduces the incentive toward uniform practices, the presentation of a standard accepted practice is not expedient at this time.

That techniques and methods of procurement and selection are in a stage of development, rather than in a state of standard practice, is not to be construed as an indication that the problems are considered of secondary importance. On the contrary, the investment in personnel for research is an item in the company budget which cannot be considered trivial. Each research engineer can be considered, based upon the interest value of his yearly salary, an investment of a hundred thousand dollars. If the value of the equipment and supplies the worker uses is also considered, it is apparent that efficient use of this investment, through the selection of research workers with high productive value, may be considered a most important administrative task.

Procedures for Developing Sources of Research Personnel

In war periods the educational system is disrupted by special training programs and the normal flow into industry of graduates

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This chapter by A. G. Ashcroft, Director of Research, Alexander Smith & Sons Carpet Co.

and those with advanced degrees does not occur. In such times the procurement of personnel is difficult and a discussion of methods formerly used has no practical meaning. There is no assurance, however, that there will be an early return to conditions of personnel supply similar to those existing before World War II. That prewar period, therefore, cannot be looked upon as an adequate basis for planning.

There is every indication, rather, that not only will the personnel available during the early postwar years be far below normal demands,[15] but that the demand will also be greater because of expansion of research facilities and personnel planned by many companies.[13] There is little doubt, however, that methods found helpful in procurement and selection in the past will be expanded and developed and that research directors will carefully investigate each new technique.

The problem of procurement of personnel is not solved by the adoption of a *single* method. It requires the systematic development of all available sources of personnel in the educational and industrial system.

Procedures at the High-School Level

In some laboratories procurement contacts start at the high-school level. Contacts with prospective professional personnel so far in advance of completion of the educational process are designed to improve later the chances of wise selection, and to encourage the interest of the top mathematics and science students in industrial research as a vocation.

The process followed by some laboratories [1] is as follows: In May of each year, the guidance counselors of the local high school are contacted. They are asked to select, with the aid of the science teachers, the top 10 per cent of the students in mathematics and the sciences. These students are rated by school marks, intelligence tests, teachers' and guidance counselors' comments,[9] and are given a vocabulary test and an aptitude test. They are then interviewed by personnel department and laboratory supervisors and a selection made of from five to ten students to be offered positions as trainees. Trainees start as full-time laboratory helpers during the summer between their junior and senior years, and as part-time (two to five P.M.) workers week-days during their senior year. During their employment they work as helpers in control testing and later as helpers on research or development. Their training and rating are carefully developed, and on their graduation from high school it is possible to select several who can be offered summer employment during their college years, and otherwise encouraged to consider the company as their future employer on completion of their engineering or scientific courses. A further advantage of this early selection is the encouragement it gives to "home-town" students of ability to consider the employment opportunities near their homes when they are recruited by large laboratories away from their homes.

A variation of the trainee course as a means of contact with top students at the high-school level is used by some companies. Scholarships are offered to students in local high schools by industrial firms,[2] and various means of selection,[5] usually in the hands of the high-school teaching staff, are used. Although these scholarships have no strings attached as to place of work on graduation, the research laboratories usually encourage summer work between college terms so that a natural selection develops.

One of the most interesting extensions of the selection and scholarship idea at the high-school level has been carried on in the past few years by a science magazine,[6] and sponsored by one of the largest electrical manufacturers. It is called a "Science Talent Search" and reaches all parts of the country. Tests are given to high-school seniors and they write research papers. The field is finally narrowed down to fifty who are entertained in Washington, D. C. Full scholarship awards, based upon a number of additional tests and interviews by educators and psychologists, are given to those considered the best potential scientists. No effort is made to restrict award winners to special fields of education, or to specific job acceptance upon completion of their college studies.

Procedures at the College Level: Co-operative Studies

Experience with co-operative students in procurement and selection of research workers has been of mixed value. Some laboratories report excellent results and make continuous efforts to maintain employment contacts of this type. Others are outspoken in criticism of details in the programs, such as interruption of research work at regular intervals, difficulty of maintaining the plan through all seasons of help demands, and caliber of co-operative students available.

There seems to be general agreement, however, that where the co-operative system has been actually tried out at the graduate, rather than the undergraduate, level, results in procurement and selection of personnel have been excellent. There is little doubt that it is a contact potential for procurement of research workers which, if carried out in a college or university within reasonable proximity to the laboratory, and in an institution with co-operative education as a fixed plan in its curriculum,[14] has real advantages worthy of development.

Summer Employment

Many laboratories use summer employment as a major method of procurement and selection. Contact with prospective graduates on the basis of temporary employment seems one of the most satisfactory methods in the opinion of research directors. Some laboratories recruit undergraduates in sophomore and junior years for summer employment as a method of pre-graduation selection. At least one large research laboratory in the mechanical equipment field combines a thorough and carefully developed method of selection of sophomores in several near-by colleges with summer employment, with training courses, and with encouragement and help in graduate studies, to procure and select desirable research men long before others have approached them. The development of schemes of this type for procurement and selection prior to graduation from college is a noticeable trend in the recruiting of research personnel.

College Contacts

Some laboratories have used training courses as inducements to college graduates and as an area of selection of research workers. The General Electric Company considers its training course the best method it has found for selection of the research worker type. The training course General Electric has evolved is a highly developed, specialized, postgraduate course of eight months with a mixture of theoretical and shop training. Grading, rating, and analyzing of student aptitudes and interests are well organized, and it is reported that worker assignment to the varied divisions of the company's technical effort is relatively clear-cut. Outstanding students are retained for a succeeding year as instructors and are frequently assigned to research work. In this method of combining procurement with selection, it should be noted that, as in summer employment contacts and trainee courses at the high-school level, the emphasis in selection is a long-time contact with prospective research workers *before* actual employment as a research worker really occurs.

Graduate Students

Procurement of personnel through personal contacts with teaching personnel at colleges and at endowed research institutes is perhaps the most common method in use by research directors. Many companies have developed regular plans of contacts with placement managers, deans of colleges, and professors. By personal visits at a regular time each year, their representatives interview and study the records of undergraduate seniors, some of whom have been previously interested in employment possibilities with those companies with organized plans of employment of a number of research workers each year. This scheme of selection is best adapted to the larger laboratories who employ a number of new men each year and have an established record of satisfactory results in employment. As they are able to select from the upper brackets in academic standing, the smaller laboratories may find it difficult to compete with the volume and prestige of their recruiting.

A similar method of contact with graduate students is used by some laboratories, usually early in the year of completion of the graduate work, and sometimes in combination with prior summer employment.

The General Electric Company stresses its use of "a short, fixed employment period prior to receipt of the doctorate degree with a definite terminating engagement for the end of the period, either a job or college, so that neither he nor we shall be embarrassed by the termination, nor our judgment warped by considerations other than the main one of fitness." If they still think well of him, and he of them, after a six-month cooling-off period, "the choice is likely to be satisfactory." There is no assurance, however, that the field of able research engineers has been or will be completely combed in this way, since recognition of research aptitude at the undergraduate level is not necessarily established by academic standing or faculty intuition.

Advertising

Directors of research have given little emphasis to procurement of personnel by advertising or through employment bureaus. There has been some evidence that these methods are useful, particularly in channels afforded by the journals and placement bureaus of scientific and professional societies. In general, however, these techniques of procurement are supplementary and are used primarily for recruiting of specialized research personnel at the postgraduate level and of those with special training and experience. Some agencies that have been used with varying success are: U. S. Employment Service, National Roster of Scientific Personnel, the American Chemical Society Clearing House, etc.

Procedures at the Graduate Level: Fellowships

The recognition of the value of developing graduate training and a long-range interest in the stimulation and encouragement of fundamental research has resulted in an extension of industry's financial contributions in these directions. In recent years there have appeared notable additions to the number of companies contributing to fellowships for outstanding students.[8] These fellowships have been given to all types of institutions but it is likely that a greater proportion than in the past are going to colleges with organized research institutes or to those having notable scientific training in special scientific fields.

Fellowships of this type tend to develop in specialized fields the most capable research men who, under competent educational direction and while acquiring advanced degrees, receive training which fits them peculiarly for industrial research. A large number of men who have come along that path are today directing research in some of the large industrial laboratories.

Research Institutes

A growing field for the training of research workers for later employment in industrial research laboratories is in research institutes attached to colleges and universities. To established institutes, such as Mellon, Battelle, Armour, can be added others of a similarly endowed group and supported by industrial research contracts, and a somewhat newer type organized to serve special industrial fields, such as the Institute of Paper Chemistry, the Oil and Gas Institute, the

Textile Research Institute, and many others. Fellowships, and other contributions by industry, constitute a liaison with research workers in these institutes frequently leading to employment in industrial laboratories. Selection of research workers from sources such as these—from, in fact, all sources at the graduate level—is based not merely upon estimates of a man's aptitudes, but upon demonstrated successes in the field. Obviously, assuming personality and temperament compatible with conditions in applied research in an industrial laboratory, such selection presages success.

Procedures for Selection of Personnel: General

It is difficult to separate sharply the procedures of procurement from those of selection. In some circumstances of employment for research, factors other than *estimates* of research aptitude are paramount, while in many instances post-employment training is of definite importance. It is true, however, that at the earlier educational levels, selection among available men of similar training and experience is a necessity. It is at this point that history, classified experience, and recorded techniques offer little of a helpful nature in screening to the personnel manager or research director. Little has been written on the qualities needed for success in industrial research, and less on how such qualities may be measured or estimated.

There is some indication that personal character [10] and attitude toward work are more important qualities than knowledge, but no proved method is available for measuring the virtues of honesty, generosity, self-discipline, courage, and tolerance. Members of the Industrial Research Institute have under study the problems involved in the classification of the qualities for successful research workers and the measurement of these qualities, but it is evident that the problem has tremendous scope and will not permit a simple, early solution.

The Use of Educational Records

Educational records, whether at the high-school or college level, offer the first evidence of attitude toward work and ability to learn. They are, therefore, an obvious early measure of some aptitudes for research. Records of educational grades, when combined with opinions of instructors and others in contact with students during their schooling, are a common and useful method of preliminary screening. They are particularly useful, certainly, in screening out the lower 50 per cent since the comparative aptitude for acquiring knowledge is of more importance in research than in many fields of industrial activity where the new and untried is a less frequent event.

The Use of Data from Application Forms

Application forms specially designed for research workers have been developed by some companies—one developed by a committee of the Industrial Research Institute is shown on page 224. In this form is combined most of the information considered essential by the committee, but the data it is designed to obtain are not weighted in such a way as to suggest selection based upon the information obtained. Forms used by some companies are shown on page 227. At their best, therefore, application forms of these types permit the orderly collection of information considered essential; when combined with other data they aid in selection.

Use of Personal Recommendations

Personal recommendations have not received a high rating as an objective basis of selection; they are used in most cases as a supplementary screening technique but with certain safeguards. Some research directors emphasize the use of personal contacts with references, rather than letters, and others have stressed the value of the telephone in this connection. If a letter is used to solicit information from former employees or others it would seem best to supplement the letter with certain safeguards, such as a well-developed form of questions to be answered and a stamped return envelope. A sample form and letter of this type are shown on pages 233 and 234.

Use of the Planned Interview and Interviewing Methods

Greater emphasis is placed by psychologists upon the planned interview as the most helpful means of effective selection of research personnel than is given any other procedure for selection. It is significant, however, of the barrenness of detail throughout the whole area of selection techniques that planned interviews designed particularly for use in selection of research personnel have not, apparently, been developed. A check list and rating form to be used in interviewing professional personnel has been presented for the information of members of the Industrial Research Institute by its

Attach recent
Photograph
or
Snapshot
here

TECHNICAL PERSONNEL EMPLOYMENT APPLICATION

Social Security No. Date

Name Address
Date Available Tel. No. Exchange
Position desired (First Choice) Second Choice
Salary Expected Last Salary received

Date of birth Height Weight
Birthplace Citizen of
If naturalized give date Date of first papers
List known physical defects
What are your hobbies?
Are you presently employed? Why do you desire to leave?
Have you ever worked for this Company? When? Where?
In what capacity?
Do you have relatives or acquaintances working for this Company? Who?
Do you object to going to any part of the United States?
Have you ever been charged with executive responsibility? What capacity?

Over how many subordinates?
Check marital status—Single Married Widowed Separated
How many persons are dependent upon you?
May we contact your present employer?

GIVE SEVERAL REFERENCES—BUSINESS ASSOCIATES OR PROFESSORS (NO RELATIVES)

Name	Address	Business or Position	Years Known

EDUCATION

Name of high school..Year left............Grade completed...............

College attended..Year left............Grade completed...............

Degrees received..Majors..

Minors..Thesis work......................................

Languages—Read..Speak..

List societies, fraternities, honors, etc...

....

Any extracurricular activities..

....

EMPLOYMENT HISTORY

Name and address of employer...

Name and title of supervisor..

Position you held..

Period of employment...Salary received.....................

Reason for leaving...

Name and address of employer...

Name and title of supervisor..

Position you held..

Period of employment...Salary received.....................

Reason for leaving...

Name and address of employer...

Name and title of supervisor..

Position you held..

Period of employment...Salary received.....................

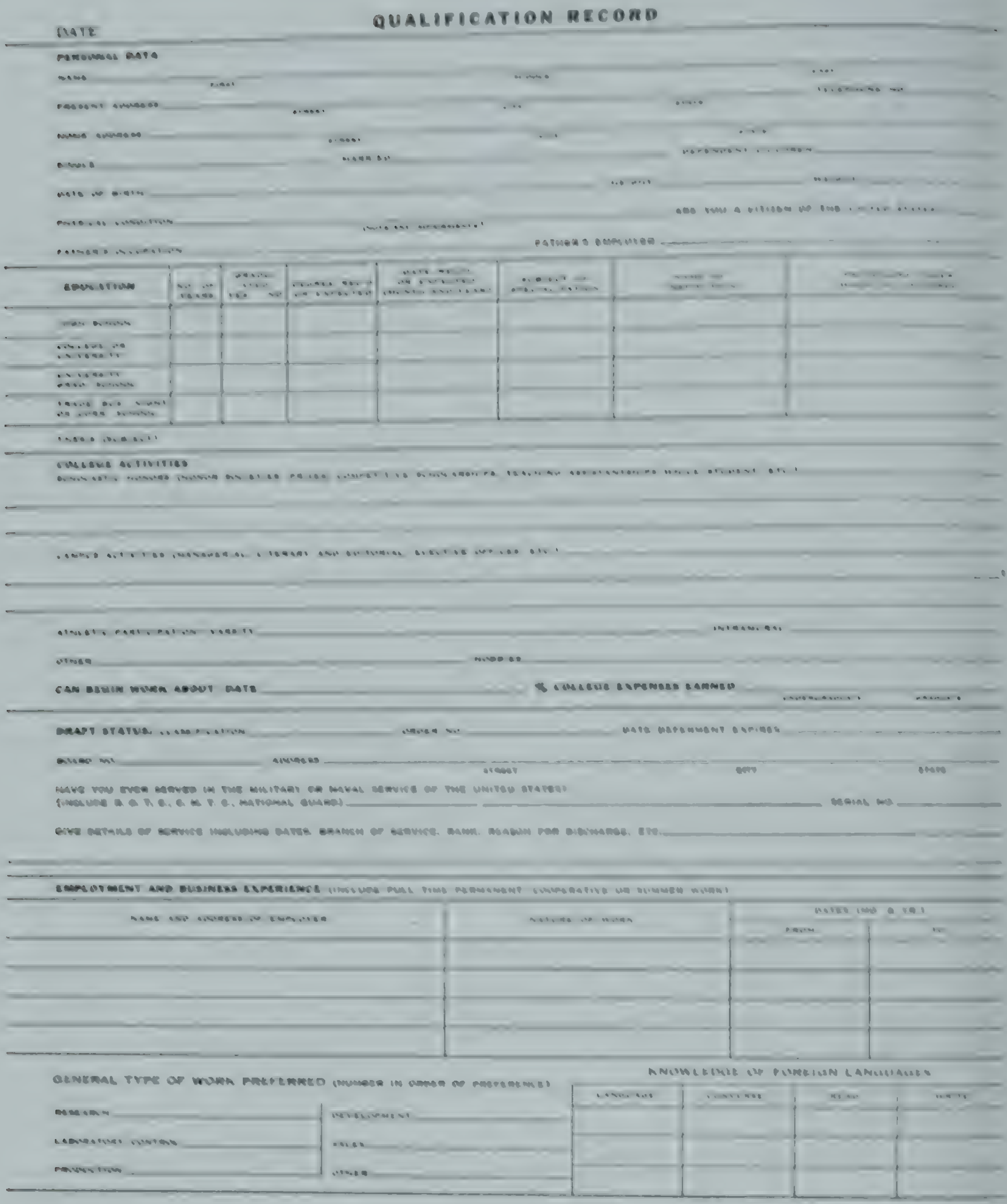
Reason for leaving...

It is understood that this application in no way obligates this Company to accept me for employment.

This application is submitted with the full understanding also that any agreements reached are contingent upon my ability to pass a physical examination as specified by the Company.

As long as I desire employment with this Company, I will keep this application up to date. Unless I renew it at the end of six months, you may remove it from your active files.

Signature of applicant...



QUALIFICATION RECORD

DATE

PERSONAL DATA

FATHER'S EMPLOYER

EDUCATION

COLLEGE ACTIVITIES

CAN BEGIN WORK ABOUT DATE

% COLLEGE EXPENSES EARNED

DRAFT STATUS:

DATE DEFERMENT EXPIRES

STREET CITY STATE

HAVE YOU EVER SERVED IN THE MILITARY OR NAVAL SERVICE OF THE UNITED STATES?
(INCLUDE R. O. T. C., C. M. T. C., NATIONAL GUARD)

SERIAL NO.

GIVE DETAILS OF SERVICE INCLUDING DATES, BRANCH OF SERVICE, RANK, REASON FOR DISCHARGE, ETC.

EMPLOYMENT AND BUSINESS EXPERIENCE

GENERAL TYPE OF WORK PREFERRED (NUMBER IN ORDER OF PREFERENCE)

KNOWLEDGE OF FOREIGN LANGUAGES

APPLICATION FOR TECHNICAL EMPLOYMENT

Research & Product Engineering Laboratories

Name .... First .... Middle .... Last .... Date ....

Present Address .... Phone No. ....

Home Address.. Phone No. ....

Date of Birth .... Height .... Weight .... Physical defects if any? ....

Married .... Widowed .... No. of Dependent Children ....

Single .... Divorced .... Other Dependents................................

Relatives Employed by this Company ....

Position Applied For:..

Salary Expected .... Last Salary Received..........

When could you start.. Were you ever employed by this Company ....

EDUCATION

	Name of School	No. of Yrs. Attended	Did you Graduate	Degree Received	Year	Major Subject
Grade						
High						
College						
Advance Courses						
Special Courses						
Trade						
Business Corresp.						

DETAILS OF SCHOLASTIC TRAINING

Give full name of course, not its catalogue number. Record completed courses as well as those being taken at present time

CHEMISTRY			PHYSICS			MATHEMATICS		
Name of Course	Time Pursued ½ Yr. etc.	Grade	Name of Course	Time Pursued ½ Yr. etc.	Grade	Name of Course	Time Pursued ½ Yr. etc.	Grade

ENGINEERING COURSES			BUSINESS ADMINISTRATION			ENGLISH COURSES		

Graduate Degree Institution Major Subject

Professor Minor Subject

Thesis subject Where published Date Page #

Membership in Professional and Honorary Societies

Give names of societies

Most interesting subjects studied in college?

What was your average grade in school High School College

In what fraction of your graduating class did you stand (upper ½, upper ¼, etc.)

Scholarships and fellowships received?

Other scholastic honors?

Did you do outside work during your school year? How much?

Percent of expenses personally earned

Did you engage in extra curricular activities?

Explain

Any special responsibilities?

Give details

Would you rather work alone or with a group?

Have you any special abilities?

Have you a shop in your home? Do you like to work with tools?

Do you think you have inventive ability in any degree?

Why

Have you ever taken out any patents?

What are your present hobbies or avocations?

Technical articles published:

REFERENCES:

Do not refer to mere acquaintances, previous employers, or relatives. Refer to people who know you well. Name one from if possible.

NAME	ADDRESS	OCCUPATION	REMARKS

PREFERENCES:

a. Along which general line of work would you prefer to advance? If you have several choices, indicate first, second, etc.

1.—Sales
2.—Sales Engineering (Sale of technical products)
3.—Maintenance Engineering
4.—Production
5.—Management
6.—Research
7.—Semi-plant Development
8.—Plant Control Laboratory work
9.—Analytical Laboratory work
10.—Time Study

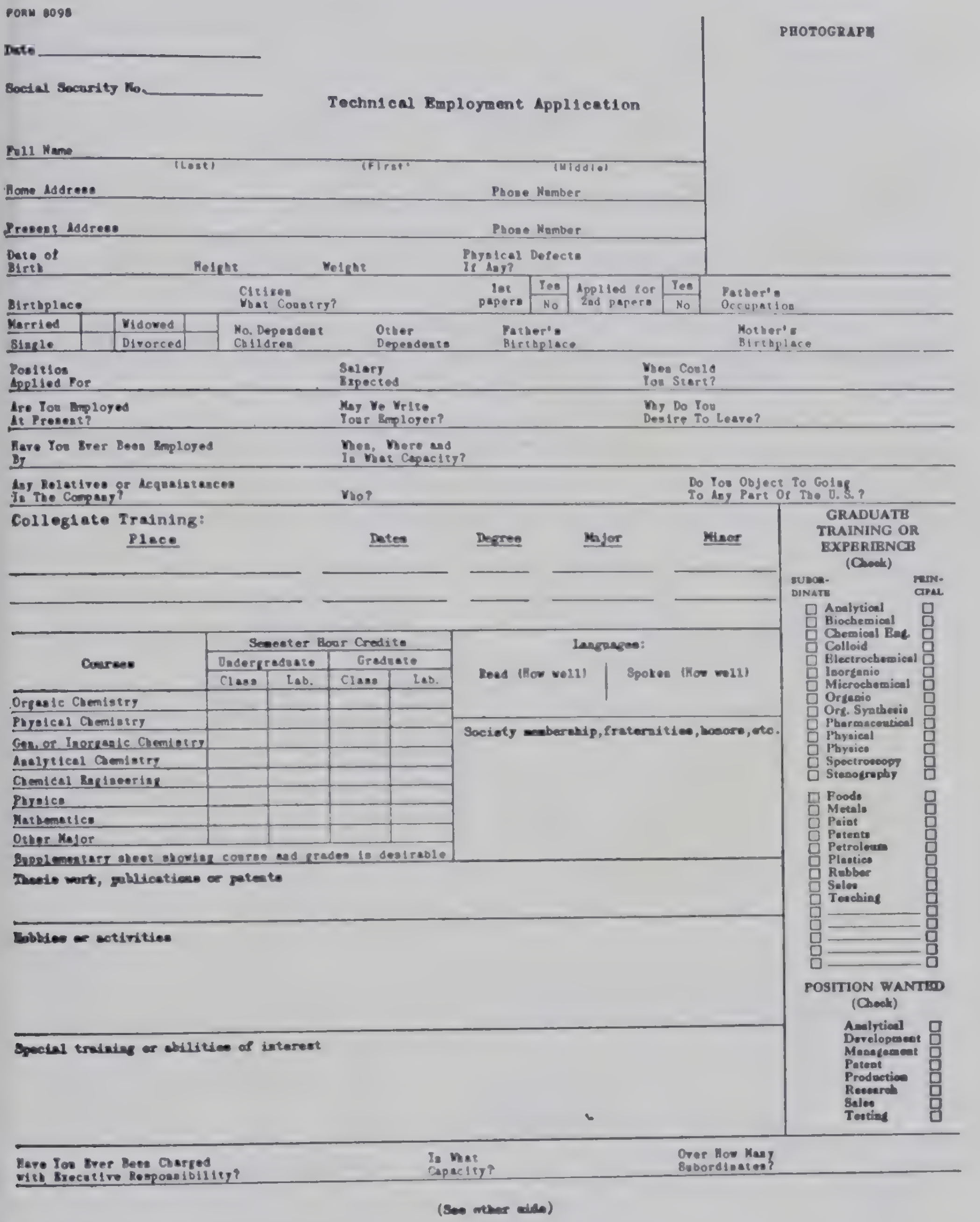
a. Are there any of the lines of work given above which you actively dislike or object to?

What kind of job do you expect to hold 20 years from now?

Explain your choice. Is it because you like the type of work or because you think your abilities run along that line? If the latter, state why you think so

RECORD OF PRESENT & PREVIOUS EMPLOYMENT

Name and Address of Employer	Business	Employed		Men Under Control	Pay		What Did You Do In Each Job and Why Did You Leave?
		From	To		Start	End	



FORM 8098

Date ____________

Social Security No. ____________

Technical Employment Application

PHOTOGRAPH

Full Name ____________ (Last) (First) (Middle)

Home Address ____________ Phone Number ____________

Present Address ____________ Phone Number ____________

Date of Birth ______ Height ______ Weight ______ Physical Defects If Any? ______

Birthplace ______ Citizen What Country? ______ 1st papers Yes ☐ No ☐ Applied for 2nd papers Yes ☐ No ☐ Father's Occupation ______

Married ☐ Widowed ☐ Single ☐ Divorced ☐ No. Dependent Children ______ Other Dependents ______ Father's Birthplace ______ Mother's Birthplace ______

Position Applied For ______ Salary Expected ______ When Could You Start? ______

Are You Employed At Present? ______ May We Write Your Employer? ______ Why Do You Desire To Leave? ______

Have You Ever Been Employed By ______ When, Where and In What Capacity? ______

Any Relatives or Acquaintances In The Company? ______ Who? ______ Do You Object To Going To Any Part Of The U.S.? ______

Collegiate Training:

Place	Dates	Degree	Major	Minor

Courses	Semester Hour Credits			
	Undergraduate		Graduate	
	Class	Lab.	Class	Lab.
Organic Chemistry				
Physical Chemistry				
Gen. or Inorganic Chemistry				
Analytical Chemistry				
Chemical Engineering				
Physics				
Mathematics				
Other Major				

Supplementary sheet showing course and grades is desirable

Languages:

Read (How well)	Spoken (How well)

Society membership, fraternities, honors, etc.

Thesis work, publications or patents

Hobbies or activities

Special training or abilities of interest

GRADUATE TRAINING OR EXPERIENCE
(Check)

SUBORDINATE		PRINCIPAL
☐	Analytical	☐
☐	Biochemical	☐
☐	Chemical Eng.	☐
☐	Colloid	☐
☐	Electrochemical	☐
☐	Inorganic	☐
☐	Microchemical	☐
☐	Organic	☐
☐	Org. Synthesis	☐
☐	Pharmaceutical	☐
☐	Physical	☐
☐	Physics	☐
☐	Spectroscopy	☐
☐	Stenography	☐
☐	Foods	☐
☐	Metals	☐
☐	Paint	☐
☐	Patents	☐
☐	Petroleum	☐
☐	Plastics	☐
☐	Rubber	☐
☐	Sales	☐
☐	Teaching	☐
☐	________	☐
☐	________	☐
☐	________	☐
☐	________	☐
☐	________	☐

POSITION WANTED
(Check)

- Analytical ☐
- Development ☐
- Management ☐
- Patent ☐
- Production ☐
- Research ☐
- Sales ☐
- Testing ☐

Have You Ever Been Charged with Executive Responsibility? ______ In What Capacity? ______ Over How Many Subordinates? ______

(See other side)

EXPERIENCE

List separately each position held. Our ability to consider you depends in great measure upon the completeness with which you furnish this information.

From (Date)	To (Date)	Give Name and Address of Employer and Position Held	Reason for Leaving	Salary Received

REFERENCE (1 Character, 1 Business, 1 School)

Name	Address	Occupation	Years Known

REMARKS: (Further information as to experience, special ability, or assets to me.)

Date on Payroll ______ Additional or Succeeds ______

Rate per Mo. ______ Approved By ______ *Signature* ______

SAMPLE OF LETTER TO REFERENCE

John Smith and Company
65 Blank Street
New York, New York

Confidential

Gentlemen:

....has applied to us for a position in our Research and Product Engineering Laboratories. We would prefer calling on you in person for information pertaining to this applicant's personal history and background, and regret that we are not able to do so. However, your frank and candid answers to the questions on the attached sheet would be greatly appreciated and naturally would be kept in strict confidence.

For your convenience in replying, please use the enclosed envelope. Should you have information you do not care to put in writing, you may telephone us collect.

Thank you very much for your co-operation.

Yours very truly,

RESEARCH AND PRODUCT ENGINEERING LABORATORIES

By:..

CONFIDENTIAL

Applicant's Name..

Date..

REPORT FROM APPLICANT'S REFERENCE

From:..Address..

1. How long and how well have you known applicant?..
....
2. Do you believe that applicant is:
   Honest ....Sober ....Dependable....................
3. Is there anything which would tend to reflect unfavorably on applicant's character or reputation?..
4. Any question of loyalty to the United States?..
5. If a former employer please fill in the following:
   A. Employed by you beginning....................Ending....................
   B. Nature of duties..
   C. Reason for leaving your employ..
   D. Would you re-employ?..
6. Do you have any information regarding applicant's family background, along the lines indicated above, which you believe would be of interest to us?....................
....
7. General Comments:

CONFIDENTIAL

PERSONALITY

Consider mannerisms, appearance, general impression	Undesirable ( )	Average ( )	Good ( )	Exceptional ( )

ABILITY TO LEARN

Consider quickness to learn and retain new methods, ideas and directions, capacity to think	Slow ( )	Average ( )	With Ease ( )	Exceptional ( )

QUANTITY OF WORK

Consider amount of work accomplished and speed of doing it	Low Output ( )	Average Output ( )	High Output ( )	Very High Output ( )

QUALITY OF WORK

Consider accuracy and thoroughness	Careless ( )	Passable ( )	Good Quality ( )	Highest Quality ( )

DEPENDABILITY

Consider reliability, willingness, consistent industry, and honesty	Unreliable ( )	Usually Reliable ( )	Reliable ( )	Absolutely Dependable ( )

JUDGMENT AND COMMON SENSE

Consider ability to see things to do, resourcefulness, aggressiveness	Needs Constant Supervision ( )	Routine Worker ( )	Resourceful ( )	Original ( )

CO-OPERATIVENESS

Consider ability to get along with people in various capacities, willingness, loyalty	Requires Prompting ( )	Indifferent ( )	Co-operative ( )	Helpful ( )

Check the type of position for which you would recommend the candidate in our Laboratories.

Synthetic Organic . . . . . ( )	Routine Lab. Work . . . . . ( )	Pilot Plant . . . . ( )
Analytical . . . . ( )	Administrative . . . . ( )	______________________ ( )
Physical . . . . ( )	Engineering . . . . ( )	None . . . . ( )

What are the candidate's eccentricities or oddities?

Signed ______________________________

Title or Occupation ______________________________

TECHNICAL PERSONNEL INTERVIEW REPORT

INSTRUCTIONS TO INTERVIEWER: This report is divided into four main parts, in each of which should be recorded observations regarding one of the following:

I. . . Professional Standing
II. . . Non-Professional Interests
III. . . Personal Appearance
IV. . . Personal Traits

Under each of these four main sections there are one or more qualities which the interviewer should try to observe or judge and indicate by underlining or checking the number which most nearly corresponds to the candidate's characteristic. The words or phrases after the various numbers are for guidance only, and are not to be taken too literally. Other expressions might have been used without changing the intent.

When you have completed all the items, arrive at an average score (by averaging the numbers checked) for each of the four main sections and mark this average score on the proper side of the "Summary Graph" at the end of the report. Finally, connect opposite points and note the zone in which the two lines intersect. This gives your over-all rating.

Candidate's Name..Date..................................

Degree.. College or University ....

I. PROFESSIONAL STANDING (As indicated by scholastic grades, position in class, honor societies, publications, etc.)

1—Excellent 2—Above Average 3—Average 4—Fair 5—Poor

II. NON-PROFESSIONAL INTERESTS (As indicated by extracurricular student activities, including self-support, hobbies; participation in sports; music; literature; general interest in world affairs; etc.)

A. *Current Affairs*
1. Well informed
2. Conversant
3. Mild interest
4. Lacks interest
5. Too much interest

B. *Hobbies, etc.*
1. Good hobbies
2. Athletics
3. Self support
4. Little interest
5. Too much interest

III. PERSONAL APPEARANCE

A. *Physique* (As indicating health and general impression on others.)
1. Impressive and vigorous
2. Pleasing and healthy
3. Negative
4. Unattractive
5. Weak and sickly

B. *Physiognomy*
1. Excellent features
2. Attractive
3. Negative
4. Unattractive
5. Repulsive

III. PERSONAL APPEARANCE (Cont'd.)

C. *Dress and Neatness*

1. Well groomed
2. Good
3. Negative
4. A little negligent
5. Definitely sloppy

D. *Poise and Manner*

1. Confident
2. Calm
3. Ordinary
4. Nervous
5. Awkward

IV. PERSONAL TRAITS

A. *Aggressiveness*

1. Forceful, confident
2. Considerable initiative
3. Average drive
4. Lacks force
5. Too emphatic

B. *Initiative in Conversation*

1. Shares and contributes
2. Receptive, average contribution
3. Listens, but doesn't contribute much
4. Neither listens well nor contributes
5. Wants to do all the talking

C. *Self-Expression*

1. Excellent
2. Good
3. Not fluent
4. Poor grammar
5. Rambles

D. *Attitude*

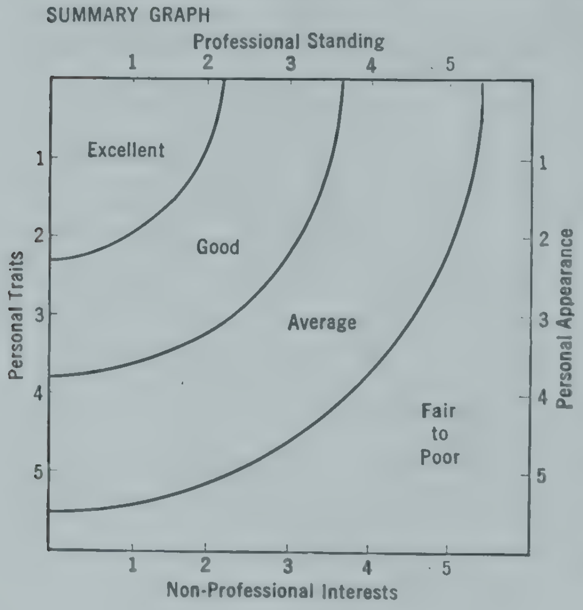
1. Frank, sincere
2. Satisfactory
3. Neutral
4. Careless, indifferent
5. Antagonistic

E. *Leadership*

1. Definitely leader type
2. Probably leader type
3. Doubtful
4. Probably not leader
5. Definitely not leader

F. *Energy (Physical)*

1. Vert active
2. Active
3. Neutral
4. Slow
5. Lazy



Suggested Disposition Based on This Interview, recognizing that final action will depend also on other elements of the selection program—history, references, etc.

Not to hire

To hire for the following:
(Underline which)

Production
Sales
Plant Engineering
Tech. Control
Research—Fund.
Research—Appl.
Process Develop.
Commercial Develop.

Signed..
Interviewer

Special Committee on Education, Selection, and Training of Research Personnel, and is illustrated on page 235. At best, this form is a guide to interviewers in the development of areas of information by conversational guideposts. It may help the interviewer touch all the bases and record values before going to the next subject.

There is little doubt that a satisfactory interview is not an accident, but rather an art. Little attention has been paid to the training of interviewers in effective psychological techniques. A discussion of techniques in interviewing is given in a booklet entitled *Employee Evaluation Manual for Interviewers*[7] by R. A. Fear and Byron Jordan, and an evaluation form is included. More detailed discussions are found in Bingham and Moore's *How to Interview.*[4] There is no question but that a complete discussion covering every detail of an interview and the interpretation of its findings would be a book itself. But it is not inconceivable that an outline of planned interviewing of research personnel may be a research project of the not too distant future.

In the literature on this subject,[12] whether emphasis on the bases for selection is on psychometric or upon psychiatric methods, the relative importance of the interview as a source of information is invariably stressed. There is a constant danger that without the use of more scientific methods in interviewing, selection based solely upon interviewing may be more physiognomic than an inexperienced interviewer might consider likely.

Some companies employ psychologists full time as aids to the development of employee selection techniques, and training and rating methods. The research laboratories of these companies utilize these specialists for special help in selection methods for research personnel, but there has been no publication of such techniques that have been found useful.

Trial Periods, Observation and Training Programs in Selection

While methods such as pre-employment trial periods and training programs are primarily helpful in the development of sources of junior research assistants at the undergraduate level, they are also helpful in that they permit longer periods of observation of the trainee and thus support or contradict predictions from interviews, tests, and history. It is not infrequent, also, that latent aptitudes and interests in research methods, hitherto more or less secondary in the younger personnel, are developed by trial and training periods. This section of the book cannot include a discussion of employee rating methods, but it should mention that the use of formalized employee rating methods is especially indicated when trial and training programs are used.

Aptitude Testing Techniques and Psychological Tests

The increased use of test techniques in selection and placement of specialized personnel in our armed forces has served not only to popularize testing generally as an aid in selection, but to develop a large body of experimental data on the efficacy of these test methods and an increased number of psychologists and psychiatrists with training and experience in the field of selection. While little attention has been given to the use of these techniques specifically in the selection of specialized scientific personnel for industry in the past, it appears fairly certain that interest in such tests is growing. Some industries have experimented with test techniques for sales personnel and are trying special aptitude tests for less specialized personnel. There appears to be little evidence in published form that test techniques are an easy substitute for other selection methods and there is some danger that invalidated tests may be more misleading than helpful.[3] There is evidence of strong opinion that the selection of men of ability for research work by means of testing alone is practically worthless. It might be pointed out, for example, that research material can be made or broken by the leadership in the research laboratory, and that the research director himself is therefore a predominating factor in the effectiveness of the research workers.

In the Science Talent Search [6] program, tests are a part of the selection technique both in the preliminary screening and in the final selection of the scholarship winners. Copies of these specially designed tests have been published and their efficacy may be demonstrated by careful follow-up on the contest winners in future years. A joint committee of the Society for the Promotion of Engineering Education,* the Engineers' Council for Professional Development, and the Carnegie Foundation for the Advancement of Teaching has been working on a battery of tests designed to aid in screening students in engineering, and has reported on its analysis of a series of six tests called the "Yale Scholastic Aptitude Tests." [9] In this series, as in many others, a test in verbal comprehension or vocabulary is discriminating and seems valid for distinguishing good from poor students. It would appear that there is agreement that some elements of aptitudes for scholastic training are measured by command of the English language, but there is no factual evidence that these aptitudes are independent of others or a primary need in successful research engineers, although they may be significant in the development of a successful director of research.

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* Became American Society for Engineering Education, June, 1946.

Before a test for research workers is developed, it would seem axiomatic that careful studies of the elements of personality and aptitudes, which are the basic sources of success in this highly specialized scientific field of industrial activity, are required. Such studies have not as yet been organized although members and a committee of the Industrial Research Institute have been discussing the organizing of such a project in recent years. If such a research project is started and special tests are developed for the selection of research chemists or research physicists, or research workers generally, present opinions of psychologists indicate that such tests will form one of the three major elements in selection rather than operate as a single conclusive basis for decision.

It is the opinion of Dr. George K. Bennett, for example, that superior research personnel can be successfully selected through a combination of:

1. An evaluation of their past achievements in school and at work;
2. A properly selected battery of tests; and
3. An interview appropriately planned and conducted.

Some of the qualities considered essential in research personnel which might distinguish them from salesmen, administrators, production supervisors, and others in industrial activities, are:

Knowledge of the scientific field.
Superior intelligence.
Ability to write reports and speak well.
Ability to produce new ideas—Imagination.
Persistence in the face of difficulty.
Curiosity and a desire to solve problems.
Possession of certain character traits, including honesty, generosity, self-discipline, courage, and tolerance.
Attitude toward work.

Ability to analyze and develop an organized attack on the problem, rather than dependence upon an inspired attack.

Competence in recording and interpretation of data.

To this brief list, other elements can be added. A well-designed research project would no doubt result in both completeness and a *weighted* classification of essential knowledge, personality traits, and special aptitudes such as creative ability.

The present status of available tests does not permit the recommendation of certain test batteries already developed since, in general, they have neither been validated nor specially designed for the selection of research workers in industry. Those interested in experimental study of available tests, in combination with appropriately planned and directed interviews and history, might wish to be familiar with some types of tests available. It is recommended, however, that the subject of psychometric classification of individuals for research is not a field for a part-time study, but deserves the complete attention of qualified and experienced psychologists. A few classes of test types may be mentioned as of interest:

The Mechanical Comprehension Test, Form BB
    The Psychological Corporation
    522 Fifth Avenue, New York, N. Y.
Engineering and Physical Science Aptitude Test
    Extension Test Service
    Pennsylvania State College
Stanford Scientific Aptitude Test
    Stanford University Press
    Stanford University, Calif.
Yale Scholastic Aptitude Tests
    Yale University, New Haven, Conn.
Vocational Interests Tests
    Dr. E. K. Strong
Johnson O'Connor Test Batteries
    Human Engineering Lab., Inc.
    11 East 62nd Street, New York, N. Y.
Humm-Wadsworth Temperament Scale
    Doncaster G. Humm Personnel Service
    1219 West 12th Street, Los Angeles 15, Calif.
Minnesota Multiphasic Personality Inventory
    Psychological Corporation
    522 Fifth Avenue, New York, N. Y.
Miscellaneous English Vocabulary Tests

Almost all of these tests have been developed with the high-school graduate or first-year college freshman in mind. They tend to group together all forms of engineering interests and thus presume to include industrial research aptitudes. In addition, verbal tests predominate in group tests designed to measure ability to absorb and reproduce ideas in written form. To the degree to which this may be over-weighted in success in research, the tests are correspondingly invalid for selection of research workers.

One of the first steps in a definition of the abilities and aptitudes of research workers in industry would be, obviously, a classification of the types of research workers in industrial laboratories and a defition of their duties and responsibilities. A special committee of the Industrial Research Institute has developed a tentative standard classification which, after distribution and correction, a majority of the members agreed represented a general classification to the extent that any general standard of that nature could represent such diverse practice in titles and duties of workers in research laboratories. This classification is shown on pages 242 and 243.

A later effort of the Special Committee of the Industrial Research Institute studying this problem was to attempt to add to the classification illustrated on pages 242 and 243, job descriptions and qualifications. A draft outline of job descriptions and qualifications is shown at the end of this chapter. This outline is necessarily in a stage of development but it can be used as a basis for more complete job descriptions and qualifications. In its present form, the classification is a rough guide to the description of personnel in present day industrial research laboratories.

Summary

This discussion of procurement methods and selection techniques is developed to indicate the paths of action frequently followed, and the trends in the development of *improved* techniques, which appear to be in process. As more directors of research recognize the importance of safeguarding the effectiveness of the large investment in personnel, and as competition in research increases, it would appear that emphasis on a more scientific approach to procurement and selection methods will result.

Summary of Study of Classification of Personnel
In
Research Division of Manufacturing Organizations
by
Committee on Education, Selection, and Training of Research Personnel

Class No.	*Descriptive Name*	*Group Class*
1.00	Trainee	Technical
1.01	Laboratory Helper	"
1.02	Shop Helper	"
1.03	Maintenance Helper, etc.	"
1.04	Watchmen	"
2.00	Technician, Third Class	"
2.01	Research Assistant, Third Class	"
3.00	Technician, Second Class	"
3.01	Research Assistant, Second Class	"
4.00	Technician, First Class	"
4.01	Research Assistant, First Class	"
5.00	Assistant Engineer	Professional
5.01	" Chemist	"
5.02	" Physicist	"
5.03	" etc.	"
5.04	" etc.	"
6.00	Engineer	"
6.01	Chemist	"
6.02	Physicist	"
6.03	etc.	"
6.04	etc.	"
7.00	Senior Engineer	"
7.01	Senior Chemist	"
7.02	Senior Physicist	"
7.03	" etc.	"
7.04	" etc.	"

Class No.	*Descriptive Name*	*Group Class*
1.10	Clerk, Third Class	Clerical
2.10	Clerk, Second Class	"
3.10	Clerk, First Class	"
4.10	Chief Clerk	"
5.10	Librarian	Professional
6.10	Engineering Librarian	"
1.20	Tracer	Drafting
2.20	Draftsman, Third Class	"
3.20	Draftsman, Second Class	"
4.20	Draftsman, First Class	"
5.20	Layout Draftsman	Professional
6.20	Design Draftsman	"
7.20	Inventor	"
1.30	Typist	Office
2.30	Stenographer	"
3.30	Secretary, Second Class	"
4.30	Secretary, First Class	"
5.30	Office Manager	"
5.31	Accountant	"
2.4	Mechanic, Third Class	Mechanical
3.4	Mechanic, Second Class	"
4.4	Mechanic, First Class	"
5.4	Chief Mechanic	"
6.4	Shop Supervisor	"
8.00	Group Leaders	Administrative
8.01	Section Heads	"
8.02	Special Engineers or Scientists	"
9.00	Assistant Department Chiefs	"
10.00	Department Chiefs	"
11.00	Assistant Director	"
12.00	Director	"

DRAFT OUTLINE OF JOB DESCRIPTIONS AND QUALIFICATIONS OF CLASSIFICATION OF PERSONNEL IN RESEARCH DIVISIONS OF MANUFACTURING ORGANIZATIONS AS DEVELOPED BY THE COMMITTEE ON EDUCATION, SELECTION AND TRAINING OF RESEARCH PERSONNEL

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualifications*
1.00	Trainee	Technical	Routine assistant in laboratory work. Assists with simple tests; performs routine tests; makes records; prepares work places; cleans up work places; performs simple duties under direction of supervisors.	High-school students or young employees planning to follow scientific or engineering work. Little or no experience; no special training except scientific course in high school.
1.01	Laboratory Helper	Technical	Routine assistant in laboratory work. Assists with simple tests; performs routine tests; makes records; prepares work places; cleans up work places; performs simple duties under direction of supervisors.	Either a young person without training and perhaps without completion of high-school education, interested in scientific or engineering work, but with no educational qualifications, or an older person with no educational qualifications and limited physical or mental aptitudes.
1.02	Shop Helper	Technical	Assistant in shop; prepares work places; watches work; records data; generally assists and carries out instructions of supervisors in applied research work.	Young high-school graduate with mechanical aptitude and interested in applied research and development, or with some science education in high school; or an older person with aptitudes in mechanical work but with minimum educational and possibly other personal aptitudes.
1.03	Maintenance Helper	Technical	In general, duties are associated with the maintenance of equipment and of physical conditions in the laboratories.	Young high-school graduate with mechanical aptitude and interested in applied research and development, or with some science education in high school; or an older person with aptitudes in mechanical work but with minimum educational and possibly other personal

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualification*
1.04	Watchman	Technical	Watching equipment and facilities of the laboratory outside of regular working hours; possibly observing special apparatus in operation.	Older man, possibly with physical disabilities, without educational or other scientific aptitudes.
2.00	Technician 3rd Class	Technical	Assists in laboratory work in quality control and development, performs routine tests, makes records, performs testing duties under the direction of more experienced personnel.	High-school graduate or usually planning to continue scientific or engineering work through after-work education. Has little or no experience in this work at the start and no special work training.
2.01	Research Asst. 3rd Class	Technical	Assists in laboratory work in quality control and research, performs routine tests and experiments under the direction of experienced supervisory research men.	High-school graduate or usually planning to continue scientific or engineering work through after-work education. Has little or no experience in this work at the start and no special work training.
3.00	Technician 2nd Class	Technical	Similar work to that of Technician, 3rd Class, except that he has more experience and aptitudes and is able to carry on more work without detailed supervisory direction. Able to make sample reports, compile data, etc.	High-school graduate with some experience in testing and some experience as an assistant in laboratory work.
3.01	Research Asst. 2nd Class	Technical	Similar work to that performed by Research Assistant, 3rd Class, except that he has more experience and aptitudes and is able to carry on more work without detailed supervisory direction.	High-school graduate with some experience in testing as well as experience in laboratory work.

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualifications*
4.00	Technician 1st Class	Technical	Experienced in testing for quality control, having special aptitudes in certain tests or procedures; able to perform certain tests and carry out duties without special supervision.	High-school graduate plus additional educational qualifications, such as part college work or special experience on laboratory procedures, or long experience in specific laboratory testing work. Must be able to take responsibility and act on own initiative without continuous supervision.
4.01	Research Asst. 1st Class	Technical	Experienced in research testing, having special aptitudes in certain research procedures. Able to perform tests without special supervision and to make reports and summaries of work done.	High-school graduate plus additional educational qualifications, such as part college work or special experience on laboratory procedures, or long experience in specific laboratory testing work.
5.00	Asst. Engineer	Professional	Scientifically trained assistant to Research, Development or Control Engineer. Carries out tests and investigations under direction of more experienced personnel.	B.S. degree in engineering; interest in testing work and evidence of mechanical ability; educational and extracurricular work.
5.01	Asst. Chemist	Professional	Scientifically trained assistant to Research, Development or Control Engineer. Carries out tests and investigations under direction of more experienced personnel.	B.S. degree in science; evidence of scientific ability; educational and extracurricular work.
5.02	Asst. Physicist	Professional	Scientifically trained assistant to Research, Development or Control Engineer. Carries out tests and investigations under direction of more experienced personnel.	B.S. degree in science; evidence of scientific ability; educational and extracurricular work.
5.03				
5.04				

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualifications*
6.00	Engineer	Professional	Supervises the conduct of tests, analyses of data; investigates devices or test procedures; assumes responsibility for certain tests under the general direction of a more experienced supervisor.	B.S., M.A., or Ph.D. in engineering. Experience in testing or design work. Able to take responsibility because of training and experience in carrying out investigations, etc. Some supervisory ability.
6.01	Chemist	Professional	Supervises the conduct of tests, analyses of data; investigates devices or test procedures; assumes responsibility for certain tests under the general direction of a more experienced supervisor.	B.S., M.A., or Ph.D. in science. Experience in research work; able to take responsibility because of training and experience in carrying out investigations, etc. Some supervisory ability.
6.02	Physicist	Professional	Supervises the conduct of miscellaneous tests, analyzes data; investigates devices or test procedures; assumes responsibility for tests.	B.S., M.A., or Ph.D. in science or engineering; experience in research and control work; able to take responsibility because of training and experience in carrying out investigations.
6.03				
6.04				
7.00	Senior Engineer	Professional	Supervisor of testing work; usually in charge of a section or having special duties because of training, experience and skill. Carries out individual investigations without direct supervision except from group leaders.	B.S. in science or engineering, with considerable experience in skills or educational training, as indicated by M.A. or Doctor's degree; some experience in testing; must be able to carry out independent investigations with a minimum of supervision

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualifications*
7.01	Senior Chemist	Professional	Supervisor of research work; usually in charge of a section or having special duties because of training, experience and skill. Carries out individual investigations without direct supervision except from group leaders.	B.S. in science; with considerable experience in skills or educational training, as indicated by M.A. or Doctor's degree; some experience in testing; must be able to carry out independent investigations with a minimum of supervision.
7.02	Senior Physicist	Professional	Supervisor of research work; usually in charge of a section or having special duties because of training, experience and skill. Carries out individual investigations without direct supervision except from group leaders.	B.S. in science or engineering; with considerable experience in skills or educational training, as indicated by M.A. or Doctor's degree; some experience in testing; must be able to carry out independent investigations with a minimum of supervision.
7.03				
7.04				
1.10	Clerk, 3rd Class	Clerical	General utility clerical work not requiring special schooling or training. Prepares and maintains simple routine reports and records. May sort and file orders, invoices and similar documents. May do simple typing or use other business office equipment.	High-school student or young employee interested in office work; little or no experience or special training, although typing and stenographic training would be desirable.
2.10	Clerk, 2nd Class	Clerical	General utility clerical work not requiring special training or schooling. Prepares and maintains routine reports and records. May do simple typing, assist in filing and carrying out clerical work of a slightly more difficult type than required of a Clerk, Third Class.	In general the same as for a Clerk, Third Class, except that more experience and training are necessary.

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualifications*
3.10	Clerk, 1st Class	Clerical	Performs engineering or laboratory clerical duties which, while of a routine nature, require some years of experience, such as custodian of supplies, assistant to librarian, etc.	High-school graduate; possibly some additional clerical education or college training. Considerable experience in clerical work; ability to use slide rule, tabulate data, draw graphs, make sketches; an interest in technical clerical work would be desirable.
4.10	Chief Clerk	Clerical	Performs moderately involved clerical duties, writes orders for research or testing, maintains assignment records, follows up order of work, assists in personnel and other routine record supervision.	High-school graduate with considerable experience in clerical duties, in Testing or Research Laboratory. Ability to direct and supervise others in routine clerical responsibilities.
5.10	Librarian	Professional	Procures files and indexes information of technical and scientific nature for the Research and Testing Laboratories. Is responsible for the maintenance of the Library.	B.S. in science or engineering, or B.A. with special interest in the scientific field and possibly training in library work.
6.10	Engineering Librarian	Professional	Supervises procurement of books, technical articles, papers, patent literature, etc., and the maintenance of a library service for the engineering and technical personnel of the research or testing divisions. Carries out searches for bibliographies for papers, compiles routine reports on literature covering research projects, translations, etc.	Experienced Librarian with a definite technical background such as a B.S. in science or engineering. Capable of supervising all the services of a Librarian in an Engineering or Testing Laboratory.

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualifications*
1.20	Tracer	Drafting	Routine assistant in drafting work; traces pencil drawings in ink on tracing cloth and reproduces from sample drawings or sketches.	High-school student or younger employee planning to follow engineering work, usually has little or no experience, and no special training.
2.20	Draftsman 3rd Class	Drafting	Performs minor drafting work under supervision of more experienced personnel.	Young persons without special training and usually with less than a year's experience in drafting. Theoretical training is limited to slightly more than high-school drafting course.
3.20	Draftsman 2nd Class	Drafting	Similar work to that of Draftsman, 3rd Class, but with more experience and ability to perform some simple tasks without specific instruction. Make simple drawings; billings of materials; traces, inks, redraws, makes changes in drawings; prepares design and parts requisitions; hand letters.	High-school graduate or equivalent in theoretical training; knowledge of typing desirable; more than 12 months practical experience.
4.20	Draftsman 1st Class	Drafting	Prepares detailed drawings of equipment under section supervision; makes complete billings of material for special instruments; makes layouts from sketches; special drawings for advertising, technical articles, etc., under the supervision of a group leader.	High-school graduate plus other theoretical training, and with several years' experience in drafting work of various types.

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualifications*
5.20	Layout Draftsman	Professional	Under the supervision of group leaders, makes complete production drawings and billings of material for such apparatus from information received as a written specification or sketch; contacts members of engineering or other departments for detailed information; assists in supervision of draftsmen; capable of doing design and drafting work with a minimum of supervision.	High-school graduate with additional drafting and technical training, possibly engineering graduate or equivalent in experience and auxiliary education.
6.20	Design Draftsman	Professional	This classification may include the designer as a group leader or as a member of a group; prepares, with little supervision, drawings of special apparatus based on specifications received verbally; prepares cost estimates; lays plans for processes; assists in various ways through engineering design in research activities; schedules, supervises, checks work of draftsmen and other members of the group; supervises drafting facilities and order of work.	Graduate engineer or the equivalent in theoretical training and experience in responsibilities. Engineering, in addition to drafting, training usually a requirement.
7.20	Inventor	Professional	Independent worker using both the drawing board and pilot plant, and assemblies to develop and invent new equipment for processing a product; usually operates as an independent individual with no supervision except task assignment.	It does not seem possible to class this kind of person under specific training requirements, but he must have a record of accomplishment which justifies the top classification in the designing professional group.

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualifications*
1.30	Typist	Office	Makes typewritten copies of letters, reports and documents from longhand, printed, or previously typed originals or corrected copy. May perform minor clerical duties entirely of a routine nature, such as assisting with filing, placing data in orderly form; mimeographing or duplicating.	Usually high-school student or recent graduate, or young employee without stenographic training, but capable of typing 30 to 40 words a minute.
2.30	Stenographer	Office	Types form letters, copy work, addresses envelopes; makes stencils; operates duplicator machines; can take dictation of a routine nature, may devote some time to maintenance or preparation of department reports and records or similar clerical duties.	High-school graduate, perhaps with additional business school training; capable of typing 40–50 words a minute with training in taking dictation but little experience.
3.30	Secretary 2nd Class	Office	Fully qualified stenographer, capable of handling mail and dictation; maintains employees' and other confidential records and files; arranges for and schedules appointments; performs some clerical work; transcribes technical correspondence, etc.	Fully trained stenographer, capable of taking dictation at good commercial speeds, usually with a year or more experience in general office work, and preferably with additional scholastic training beyond high school.

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualifications*
4.30	Secretary 1st Class	Office	Performs general office work; relieves executives and group leaders of duties of a minor character; attends to and supervises general clerical work; handles personnel and important dictation and mail of supervisors; arranges appointments; has many duties of a confidential nature as agent of executives and supervisors.	A fully qualified stenographer and secretary with several years' experience, usually with considerable experience in the department. Educational qualifications are considerably higher than for stenographer, frequently involving a full college course or its equivalent.
5.30	Office Manager	Office	Supervises, directs, manages office force, including typists, stenographers, clerks; maintains records, files, office equipment; supervises pay and time-keeping records of department, etc.	Experience with particular department; usually high-school graduate as minimum training, and several years of business experience.
5.31	Accountant	Office	Develops and maintains cost-keeping records, distribution of costs by projects; reports on laboratory expense distribution.	Trained accountant having training and experience in accounting work; usually high-school and business school, but preferably college education as well.
2.4	Mechanic 3rd Class	Mechanical	Performs machine and bench operations as required by a mechanic, second class and first class, but with close supervision and direction.	Individual and mechanical aptitudes, but with little training or experience. Education usually high school or less.
3.4	Mechanic 2nd Class	Mechanical	Machine and bench operations as required by first class mechanic, but with some supervision.	High-school training or equivalent; some experience in machine and bench operations, and with record of good performance.

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualifications*
4.4	Mechanic 1st Class	Mechanical	Makes mechanical models from ideas, sketches or drawings; performs all machine and bench operations; capable of working to accuracies of plus or minus .0005″ or better; works on various classes of devices from small parts to heavy work; all work performed with practically no supervision.	Long experience and record as a capable mechanic working on a variety of mechanical jobs.
5.4	Chief Mechanic	Mechanical	Supervises shop work of mechanics, capable of directing the making of models or equipment from ideas and descriptions of research or development engineers.	Long experience which has indicated special aptitudes in the translation of new ideas into equipment. Evidence of resourcefulness, leadership, and ability to direct others in mechanical work.
6.4	Shop Supervisor	Mechanical	As chief in charge of all mechanical work in the research field is responsible for order of work; maintenance, purchase and development of mechanical equipment for carrying out research and development work. Employment and direction of mechanical personnel and collaboration with and assistance to research and development engineers.	Experience with supervision and direction of mechanical operations, particularly in carrying out in the mechanical field the projects initiated in the research and development field.

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualifications*
8.00	Group Leaders	Administrative	Generally handles the details of the routine management of the group of research or development engineers and chemists; handles research investigations only with instructions as to subject, and supervises in detail the work of his specific group or section.	Educational qualifications—graduate in the professional field with additional education an advantage, such as advanced degrees; considerable experience in carrying out research projects as an individual and in directing the work of others in carrying out research and development work is necessary.
8.01	Section Heads	Administrative	Same as group leaders.	Same as group leaders.
8.02	Special Engineers or Scientists	Administrative	Job descriptions of this type of professional worker are not easy. He is usually a special type of scientist, accustomed to working independently on long range research projects or fundamental studies, without any special administrative or supervisory duties.	This special type of research man has reached the top of the industrial picture with respect to the performance of research work. He has special and individual qualifications, either in training or in experience, for a particular field and is accustomed to working by himself on the solution of long-range projects. Long experience and training justify a special classification and absence of administrative duties.
9.00	Asst. Department Chiefs	Administrative	General supervision of departments of the research laboratories, involving all the duties of a department head and including the supervision of group leaders and their order of work, and other duties of an administrator of a department.	Demonstration of ability at direction of operations in a research laboratory. Basic scientific training and administrative ability are requisites.

Class Number	*Descriptive Name*	*Group Class*	*Job Description*	*Qualifications*
10.00	Department Chiefs	Administrative	Department chiefs, assistant directors and directors of research divide up the duties of administration of research in different ways in different laboratories. Included in the work to be successfully initiated are all of the functions of direction of research and development laboratories: Selection and training of personnel; Maintenance of order of work; Collaboration with outside laboratories; Correlation of research to business as a whole; Service to other division of the company; Development of internal organization and methods, and the development of the broad general program of the research activities of the group.	The specifications of qualifications of a research director, presented by Arthur J. Slade at the I.R.I. meeting, Jan. 1943, might be used as a basis for the qualifications of department chiefs, assistant directors, and directors of research.
11.00	Assistant Director	Administrative		
12.00	Director	Administrative		

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CHAPTER XIII

Salary Policy

Introduction

Of the many problems concerned with group administration, none is more important than that concerned with matters of remuneration including payment of salaries, bonuses, and various other forms of financial compensation. In conjunction with proper attention to personnel selection and procurement, a sound salary policy, successfully administered, manifests itself in the continual acquisition of new men of high caliber and in low turnover of capable, experienced workers. The importance of these to the continued welfare and prosperity of the company can hardly be overemphasized.

In administering salary matters, the interests of both workers and management are best served by the same approach; the policy which is most fair from the individual point of view is also most effective from that of the company. This is a part of the principle that, in general, what is good for the company's progress is also good for the individual's economic advancement. Therefore, it becomes important to indicate what a fair remuneration policy is and some of the factors essential to its successful administration.

Basis for Fair Remuneration

Above the bare subsistence level, a man's return from the social and economic order of which he is a part may fairly be made proportional to his contribution to the general welfare of that order. Of industry (workers and investors) it has been said that "earnings, individually and collectively, should represent *equitable* participation in the distribution of income from production." If all men

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contributed alike, all should share alike. But all do not contribute alike, and the fact that individuals contribute in varying degrees forms a just basis for differences in remuneration. In our complicated society, it is impossible to measure directly how much an individual contributes to the world's wealth. The basic principles become lost in a confusion of circumstance so that, in many instances, essentially irrelevant factors become potent or even dominant in determining an individual's economic status. Consequently the fundamental concepts are of use only as a foundation, not as a framework, for an effective remuneration policy.

Actually, the most vital factor in the control of individual earnings is the law of supply and demand, not in the narrow sense that wages promptly reflect the current state of the labor market,[24] but in the broadest sense possible. It is not always easy to see its influence, which may be obscured by more direct and conspicuous factors such as collective bargaining, government regulations, good will, individual character, economic cycles of prosperity and depression, luck or chance, all of which influence a man's compensation directly. But the effectiveness of each of these really depends on the law of supply and demand which is the ultimate control.

For example, in periods of great industrial activity, demand for chemical engineers may exceed the supply of competent, well-trained men, and the basic salary level they command rises. This increases the attractiveness of the field, encourages more to seek the required training in preference to some other, and thus increases the supply at the expense of fields of activity where the demand is less acute. The rest of the cycle tending to restore a normal balance may be brought on by decreased activity (demand) or by increased numbers of qualified engineers (supply) or both. The over-all effect is obviously a tendency to maintain a balanced state of affairs where men of equal capabilities will command comparable pay regardless of their chosen field of activity. The cycle is reckoned in years rather than days or weeks, but it is effective. This effectiveness is in no sense incompatible with the basic concepts of fair remuneration set forth above. A temporary situation where one group seems favored as compared with another simply measures a relatively greater need for the favored group and therefore a greater contribution by them.

What are the practical implications of all this in so far as salary policies for research workers are concerned? The influence of the law of supply and demand is one affecting only the order of magnitude, so to speak, of the compensation of the average of a broad group or class. Salary administration must be concerned with a finer adjustment and control of individual rates within the broad class. Much thought and effort have been directed toward the development of objective methods for wage and salary control, but in spite of the progress which has been made, salary administration for research personnel must still depend primarily on subjective handling. Therefore, the *character and personality of the administrators is the factor of prime importance.* On the other hand, methods which have been developed for systematizing the administration of salary matters should be used where applicable as an aid and guide to administrators in fulfilling their functions fairly and equitably. In order to be helpful, a discussion of this subject must get down to earth and indicate specific means of controlling salaries, bonuses, and the like to the best advantage of all concerned. In such a discussion we may well consider three aspects of the general subject, namely: the determination of rates, the administrative personnel, and some of the circumstances which must be considered in making decisions.

Determination of Rates

An effective remuneration policy must provide for proper adjustment of pay levels with respect to the wage structure of three successive subdivisions of the economic order: industry as a whole, the company, and the group.

In addition, the geographic area or the location in a metropolitan versus a rural area are often influencing factors. The differences between salary levels for professional people in different areas are apparently slowly decreasing. Since salaries make up the backbone of the financial return received by the majority of workers, for all practical purposes attention may be confined for the present to consideration of salaries only. In line with the above, inter-company, intra-company, and group salary comparisons must be considered.

Inter-Company Salary Adjustment

Starting rates, or the hiring rate for trained but inexperienced personnel, form the base-line for the whole salary structure of the company and therefore of the group. These rates are competitive and reflect most conspicuously the influence of the law of supply and demand.[8] In the absence of a direct measure of the worth of a man's contribution to the community, the amount the community is willing to pay for his services becomes the guide.

The "Going Rate"

Personnel departments and individuals responsible for hiring new men are ordinarily well informed on starting rates as a consequence of their contacts with educational institutions, professional society employment services, and other sources of new personnel. The categories into which inexperienced but trained workers naturally fall are not sufficiently numerous to cause confusion. Any lack of familiarity on the part of the personnel man with the current rate will soon manifest itself and be corrected; if he is not getting the men he wants, his offers are out of line. These rates are determined largely by industry itself. The competition for men offered by universities, research foundations, and similar organizations is not very effective in determining rates because in this competition considerations other than salary are usually dominant in affecting a man's choice.

To a lesser extent, rates tend to be competitive at all job levels, partly because of migration of experienced personnel and partly because of the exchange of information between employers. For instance, many concerns make a practice of periodically surveying other members of the industry on salaries appropriate for certain key jobs.[14, 19] In spite of the complexity and individual peculiarity of jobs at the higher organization levels, at every level there will be found one or more jobs which are typical throughout the industry and which can be defined with regard to the responsibility exercised by the incumbent and the training and experience required of him. These key jobs furnish reference points for the alignment of the salary structure of the group.

From time to time, various individuals or technical society groups have made surveys which attempt to determine the economic status of groups of workers as a function of years of experience, degree and type of training, field of activity, etc. Published results of some of these surveys may serve as orienting information: cf. references 1, 9, 19, 23, 25.

Intra-Company Salary Adjustments

With the over-all salary structure of the group tied loosely to that of industry by proper location on the pay scale of certain key jobs, the next step is to line up research department salaries with those of the other company departments. This adjustment should assure the research worker a wage which compares well with that received by others who are contributing in a like degree to the company's welfare. Difficulty arises in determining what positions are comparable in their contribution to company welfare. In the final analysis this will be decided by personal judgment, but to help resolve the difficulty, the methods of job evaluation may be used as a guide.

Job Evaluation

Job evaluation is not to be confused with merit rating. The former analyzes and evaluates a job objectively, defining its worth in terms of a bracket or range of rates; the latter analyzes the *job incumbent* subjectively and is the basis for the position of his salary in the bracket. Job evaluation is pertinent to the subject of intra-company, and to some extent inter-company, salary adjustment, whereas merit rating is most pertinent to intra-group salary control. Thus, job evaluation aims at fixing the value of each job relative to every other job and ultimately reduces salary administration to determining how well the individual fills the job.

A detailed discussion of job evaluation is out of place here; much has been written on the general principles and their broad application to jobs with special emphasis on the jobs of wage earners.[3, 24] There has been relatively little discussion of salaried positions,[13, 21] and still less on research jobs specifically. Further, it is probably safe to say that research positions are the most baffling to classify and define according to any objective system of evaluation. Each research job is likely to appear at first sight to be "in a class by itself," and a research department may be considered as a collection of individuals organized to function as a team. Nevertheless, the fact that much remains to be done before job evaluation techniques can be considered as established practice or as generally applicable procedure is no valid reason to dismiss job evaluation methods as inapplicable to research administration problems. Helpful job specifications do not *necessarily* include statements of specific typical operations or functions as job factors, but it is not impossible to state job factors in terms of significance to research jobs. Therefore, the subject is worthy of consideration by research administrators and the possibilities should be studied by competent men who are familiar with the particular conditions in the organization, keeping constantly in mind that such devices are to be used intelligently as an aid and guide in exercising subjective judgment.[20]

Job Factors

Certain points should receive particular attention in any consideration of the application of job evaluation methods to the research organization. Possibly the most important of these is the decision as to how far up the salary scale the system, if adopted, should be applied. Several companies have applied a formal job evaluation system to the delineation of salary ranges for non-technical employees (laboratory assistants, technicians, clerks, stenographers, etc.) and a few have even extended this to cover a considerable segment of research department personnel.[11]

The non-repetitive nature of research and the absence of any clear-cut method of immediately evaluating the results make the application of job evaluation methods particularly difficult and the difficulty increases in proportion to the complexity and responsibility of the job; the less routine the job, the harder it is to evaluate.

Intelligent attention to job factors is essential in setting up job specifications for research positions. Certain factors not usually heavily weighted in normal job specifications may be of the utmost importance to the research job. Such intangibles as originality and inventiveness, inspirational qualities, and intellectual honesty may require addition to some factor listings and additional weighting in others. In this connection it is well to point out that, in spite of the objective approach inherent in proper job analysis, the influence of the incumbent on the job cannot be ignored. No job in a research organization remains the same, nor is there any job the scope and value of which does not change with the individual who fills it. This requires constant study and frequent re-evaluation of all jobs covered by the system.

Rate Ranges

Obviously, when rates are assigned to a given job level, a range of rates rather than one rate must be set up to provide for recognition of different degrees of proficiency in filling a given job. In the assignment of rates, the relative value of the three main types of research jobs, non-technical, technical, and administrative, should be carefully considered. A considerable overlap may properly be provided between the top non-technical brackets and the brackets for beginning technical men. This follows from the fact that often a technician who lacks the fundamental training or some other prime requisite for a technical job may, nevertheless, by virtue of long experience, become of more value to the organization than a new technical man.

Technical versus Administrative Jobs

The delineation between technical and administrative jobs is impossible to draw sharply. Every technical job carries with it administrative duties if only those involved in planning a program and supervising a helper, while most administrative jobs in the research department require sound technical training and ability. Since the combination of technical knowledge and judgment coupled with the leadership qualities required in a good administrator occur less frequently than either set of qualifications alone, administrative jobs generally carry higher salary values.

On the other hand, there are always exceptional individuals particularly gifted in research whose talents would be inefficiently used if heavy administrative duties were assigned to them. Such men make an extremely important contribution to the over-all usefulness of the research division even when at times they solve no specific problem or evolve no spectacular results. Their true value to the company is, in such cases, very hard to determine because their contributions in the form of inspiration, advice, consultation, and background information may help all other workers as much as or more than themselves. Salary levels for such men require very special consideration outside the usual analysis and without regard to the individual's position on the organization chart.

Further, the fact that the research worker generally supervises the work of a small number of subordinates compared to men in jobs of comparable importance in other departments should not be allowed to influence the evaluation of his job. The relative value of the job's contribution is the important factor.

Recently there has been recognition on the part of some members of chemical industry in this country that the usefulness of the exceptionally talented individual research worker may be out of all proportion to his position in the administrative set-up.[5, 6] Of course, there have always been "geniuses" whose unique abilities set them aside from other men, but evidence of general recognition that any organization may contain men valuable as individuals rather than as members of the administrative scheme has appeared only recently. This has taken the form of new positions and titles created for the research worker, such as research associate, or research fellow, and of announced plans to make the salary scale applicable to these positions compare favorably with that of responsible administrative officials.

Other Aids to Salary Adjustment

Whether or not an effort is made to set up a complete job classification covering the whole range of research division jobs, a rough classification with wide, overlapping rate ranges is justified. Such a system will prove useful, particularly in a small organization.

As a further aid to the administrator in keeping the salary structure in order, plots of earnings versus years of service may be found useful. There are various ways of plotting, but a common method for technically trained men is monthly salary against years of service since the bachelor's degree was obtained. The bachelor's degree is a convenient reference point for all men with advanced degrees as well as men in various occupations.

Pattern curves may be made up to be used for comparison with the curve showing the progress of an individual. Such pattern curves should run for twenty or more years and may cover a variety of persons. The simplest would be one curve showing an average. Others might be for an above average person and a below average person, or there might be a whole series, each representing a class and indicated by a letter or a number.

It is very essential that definitions representing each type of individual shown by a curve be established. These definitions will vary with the business and the type of job, and at best, will not be very specific. As an example, an average man might be one who is "generally adaptable, capable of carrying sole responsibility for a major project, and able to supervise ten or more technical men, etc." A below-average man might be one who is "worth keeping, but little more, one who has to be guided on all major jobs, etc."

Pattern curves must be revised with each change in wage and salary standards.

Since this method involves subjective judgment of the worker, it is clearly differentiated from formal job evaluation, and over the range of some job levels may serve better as a guide.

Salary Control Within the Group

Placing individual salaries in their proper locations in each bracket involves some form of merit rating. Merit rating is practiced in every organization where employees are advanced in pay because of increased usefulness, whether a formal system is used or not. Use of a uniform formal system of rating will increase fairness and effectiveness. The purpose of rating scales, forms, and the like is not to eliminate subjective judgment in appraisal of a worker. Their purpose is simply to focus attention in an orderly manner on those qualities which make for an individual's success on the job or his ability to handle a bigger job.

Many excellent discussions of merit rating techniques and examples of useful rating scales have been published.[7, 12, 21] The rating of research workers can be handled in the same manner as that of other employees, using recognized forms appropriately modified to fit the circumstances. Informed and intelligent use of a rating form which has been developed with careful and competent attention to details may be very helpful in standardizing, so to speak, the recommendations to superiors, e.g., in eliminating differences due to one rater's natural enthusiasm compared with another's conservatism. Such forms are also valuable in directing the superior's attention to important qualities and in helping him see each in its proper perspective. It is even possible to assign mathematical weighting factors to each item, thus fixing the relative importance of each quality. The wisdom of such attempts at accuracy is questionable, however, as indicated by the controversy which may result when several individuals try to agree on the relative value of the items. In any event, rating scales must be most carefully and thoughtfully compounded.

Salary Administration

Whatever systems or methods are set up to act as guides in administration, there is no substitute for good judgment and a sense of fairness on the part of those responsible for making decisions. They must be open-minded, willing to listen to counsel and advice, and must know their men. The nature of research and the personnel involved cover so broad a range of variety and individuality that no "system" can be devised which will fill the role subjective judgment plays in salary adjustments. On the other hand, there should be some rules laid down whether or not formal job evaluation methods and merit rating forms are used. The objective here is to be sure that the salary administrators look at everyone alike and that important and unimportant factors are given the same, and the proper, weight in the consideration of every individual.

Administrative Personnel

Who shall make the decisions? On the basis that "two heads are better than one," group or committee action has advantages over the arrangement where one individual carries all the responsibility for taking action and making decisions. On the committee there should be at least one who is thoroughly familiar with the individual and his work, another who is familiar with the work of similar individuals in other groups, and one who knows the situation in other companies. Each independently should feel it his responsibility to suggest salary changes but the decision to change should be that of the group. Final approval for the change may be in the hands of an executive, but a wise executive will seldom feel justified in rejecting the unanimous recommendation of a competent committee.

Different committees may exist for different levels in the organization and the size of the organization will have considerable bearing on the number needed.

Merit Increases and Promotions

Recognition of unusual ability or proficiency or of a job well done may take the form of a simple increase in salary, of a promotion, or both.

Here, it may be well to point out that a promotion is generally understood to mean a transfer to another position involving greater responsibility and is recognition by management of a potentially greater usefulness on the part of the recipient. Promotions do not necessarily involve an increase in pay, but if an increase does not accompany the change of position, one should be forthcoming as soon as the employee has shown ability to handle his new responsibilities. On the other hand, a merit increase does not imply a promotion and is not necessarily recognition of ability to handle a bigger job, but of an ability to do the current job with a greater degree of efficiency and effectiveness. Both are rewards for ability and proficiency, and as such, both have an important incentive function.

No rules can be laid down to govern the timing of promotions or merit increases; circumstances will govern that. In general, one or the other should be granted promptly, as soon as merit ratings and the recommendations of the worker's superiors convince the administrators that either has been earned. It is then up to the administrators, with the advice of their colleagues in mind, to decide on a promotion or a simple increase in salary on the basis of the over-all good of the organization. There is little justification for establishing regular times at which increases and promotions are granted; it is far better for the situation to be such that the workers will feel that effort and accomplishment will be rewarded whenever they are recognized. On the other hand, the administrators should review the over-all salary structure at regular and frequent intervals.

Reviewing the Salary Structure

Some organizations have a policy of reviewing salaries on the anniversary of the individual's hiring date, rather than at fixed times throughout the year. Psychologically, the practice of granting pay increases at such times is good. Basically, however, the principle is wrong; pay increases should be granted when earned. Furthermore, salaries should be reviewed more frequently than once a year, and for new employees, particularly those in the lower brackets, will require more frequent adjustment.

The administrator may find it helpful, in reviewing an individual's salary, to have at hand a curve plotting a record of the employee's pay rate versus his years of service. Such a curve gives the reviewer a more helpful picture of the subject employee's progress and status in comparison with those of others than does a set of figures for rates and dates on which they become effective.

Effect of Outside Offers

Sometimes an individual's salary is reviewed in the light of an offer made him from the outside. Generally speaking, if a sound salary policy is in effect, promotion or salary increases should not be made solely to meet competition. This follows from the fact that one of the prime objectives of the policy is that rates shall be in line with those being paid by others. If, however, the review reveals a breakdown in the administration of the policy resulting in an injustice to the individual, the situation should be corrected immediately and entirely independently of the outside offer. It may happen that an outside offer represents a real opportunity for the individual which, because of peculiar circumstances, is not matched in his present organization. In this case, it would be unfair to all concerned if an increase, granted to offset the offer, discouraged its acceptance. Such situations are rare, however, and in a large organization salary increases and promotions should occur frequently enough to offset interest in outside offers.

Small versus Large Organizations

In small organizations where chances for frequent promotion are not great, the general salary level may be higher than average. This is justified by competition for men. Offsetting this, in the small company which may be sold or absorbed at any time, there is considerably less security to the individual and also considerably less ultimate opportunity.

Attitude Toward Merit Increase

The administration's attitude toward merit increases and promotions is one of utmost importance to the morale of the organization. There is no doubt that morale is better in an organization whose members feel that management will take the initiative in granting deserved pay increases fairly and promptly, than in one whose members feel it necessary to ask for whatever advance in pay they get. Possibly no one thing is so likely to distort a man's own evaluation of his work as the feeling that he will get only what he asks for. Such an attitude also fosters a tendency to discuss salary matters subjectively with fellow workers. Such discussions never contribute to high morale or to *esprit de corps* and usually foment discontent, or, at best, use up time and mental energy better applied elsewhere. Every encouragement should be given the idea that a man's salary is a confidential and personal matter which, in good taste, can be discussed only with those whose business it is to know it—his superiors in line of organization.

This suggestion that widespread discussion of salary matters be soft-pedaled as much as possible is not to imply that employees should not feel free to discuss salary matters at any time with their superiors or the salary policy administrators. Neither of these practices is to be discouraged, and it is particularly important that there be a frank discussion of the worker's salary problems whenever he feels it desirable. These conversations between employer and employee cannot and should not be avoided if a feeling of mutual trust and confidence is to be built up and maintained. Though painful at times, these discussions often bring to light interesting facts pertinent to the broad salary policy administration and, even more important, they often straighten out misunderstandings and uncertainties which can easily grow from minor irritations to major eruptions of real trouble.

Effect of Assignment

The nature of a man's work, his assigned problem or field of investigation, should not be allowed to influence decisions affecting his advancement. As pointed out by Shepard: [22]

> He [the research worker] must feel that whether or not the problem is solved and results in fruitful discoveries or monetary savings, he will receive due credit for his efforts if they have been conscientiously carried out, and that his promotion and salary increases will not be unfavorably affected by the fact that the problem assigned to him did not bear fruit.

Transfers and Demotions

Although not directly associated with salary policy administration, transfers require some comment in a discussion covering promotions. Aside from temporary transfers designed to fill gaps in certain spots where the work is momentarily heavy, personnel transfers are usually made for one or more of three reasons:

(1) *Personal.* Sometimes it becomes desirable from an organization standpoint to correct an unhealthy situation which may involve uncongenial personalities, as between superior and subordinate, or as among colleagues. Such a situation does not necessarily imply criticism of the individuals involved, and its correction may result in much-improved performance by men who had previously seemed mediocre.

(2) *Organization.* Often it is possible to strengthen the organization and increase employee satisfaction by transferring a worker to a different type of work. For example, a mediocre laboratory assistant may develop into an excellent draftsman, or a research man of only average promise may show that his real tastes and talents are better suited to chemical engineering and process development.

(3) *Training.* A man of promise may be shifted from one group to another to broaden his experience and train him for greater usefulness and larger responsibilities.

Transfers made for any of these reasons do not ordinarily involve either salary increase or promotion, but will probably lead to advancement for the individual sooner than would have been possible without the transfer.

Demotions should never be made except because of ill health or old age, as for example, the transfer of an individual to a position of less responsibility (and usually lower pay) to make it possible for him to carry on under a lighter load. Under any other circumstances, a demotion is a confession by the administrator of poor judgment and poor management. This, however, is not so important as the effect on the individual's morale and attitude, and its possible effect on those working around him. For this reason, if a mistake has been made and a person has been raised to a position he cannot fill, every effort should be made to correct the situation by transfer to another job at the same level.

Bonuses and Other Incentive Payments

Although practice follows no set pattern, incentive payments to research personnel over and above salary may be grouped roughly into two main categories: specific awards and discretionary bonuses. (A third type of extra remuneration, the blanket bonus which is distributed in times of good profits to all employees alike on the basis of their pay rates, length of service, and similar factors, need not be considered here, since the amounts paid to individuals are more or less automatically fixed and there are no unusual administrative problems involved. The term "discretionary bonus" is used here to differentiate bonuses paid in recognition of outstanding service from these blanket profit-sharing plans.) Administrative details vary widely from one company to another, but the general picture is somewhat as follows.

Specific Awards

Specific awards are payments made to a relatively small number of individuals in recognition of some outstanding service or contribution to the company's well-being. Such a contribution may be in the form of an invention, an improvement in a product or process, an unusually ingenious solution of a technical problem, or a suggestion which results in substantial savings or augmented profits. Specific awards are in the nature of a reward for performance "above and beyond the call of duty," and ordinarily bear no close relation to the over-all profit picture, although the decision as to the actual amount of money involved may be affected by the current state of the company's business.

Discretionary Bonuses

On the other hand, discretionary bonuses are usually more widely distributed on the basis of a more general and less specific contribution to corporate progress, and are directly proportioned to profits. Funds allocated by management for this purpose are apportioned to those individuals who, by virtue of outstanding loyalty and conscientious performance of duties, have contributed most in a general way to the company's success.

Much constructive thought and effort has been devoted to the development of so-called incentive plans for workers in production, manufacture, and distribution.[2, 15] In contrast, in the range and types of job levels here being considered, neither study nor experience has been sufficiently extensive to allow the evolution of recognized principles of administration or even of definite schools of thought.[16, 17] The difficulties involved in properly evaluating the results of research militate against the development of objective methods which might usefully supplement the exercise of subjective judgment and opinion in making decisions as to the degree to which individuals should share in bonus distribution. Consequently, as far as can be learned, all incentive payments are determined on the basis of the judgment and opinion of the administering group. Obviously intelligence and fair-mindedness on the part of the administrators is, if possible, even more important in this instance than in the case of salary control. Here, too, the advantages of group versus individual responsibility are conspicuous.

Opinions differ sharply on the advisability of paying discretionary bonuses to research workers. Some hold that bonuses should be shunned as conducive to jealousy and destructive of teamwork and that salaries are the only safe medium for the recognition of meritorious work.[4, 18] On the other hand, bonus payments are a much more flexible medium for such recognition in that they enable the employer to reward the employee for special effort without raising his salary level beyond that which the individual's work can justify.

In spite of the difficulties in administration and the consequent danger of injustices, actual or alleged, and the dissatisfaction they might cause, the advantages of paying bonuses to a fair segment of the research personnel probably outweigh the disadvantages. Certainly, incentive is no more important in any other division of the company than it is in research. The effectiveness of the incentive function may be increased by publicizing to a certain degree the fact of the existence of a bonus system, although any publicity on details should be avoided. A tradition of silence on the part of participants should be fostered; few non-participants will wholly agree with the administrators' decisions, and morale may be hurt rather than helped.

Administrative decisions in the case of specific awards are usually particularly difficult to make on an equitable basis. Results of research can seldom be evaluated promptly and directly in terms of savings, augmented profits, improvement of products, or increased production; even in retrospect, proper evaluation of research results is difficult. A further source of uncertainty is the difficulty of assigning primary responsibility for a given set of results to an individual or group of individuals. Research continually tends more toward a team effort than an individual effort, and in the normal course of developing the solution to a research problem, an indefinite number of men in addition to those primarily responsible will contribute ideas, advice, and assistance. It is even conceivable that the real pay-off came as a result of a suggestion or an idea contributed by someone outside the particular group involved.

Specific awards generally involve amounts of money (or their equivalent in stocks) substantial in comparison with the recipient's salary. This follows naturally from the fact that a specific award is usually a "once-in-a-lifetime" proposition, while bonuses may be annual affairs.

Bonus payments are generally smaller. In the payment of bonuses, some companies divide payments into two or more portions, the portions to be paid annually. This has the advantage, from management's viewpoint, of increasing the recipients' incentive to stay on with the organization.

Summary

A satisfactory remuneration policy must provide for proper adjustment of individual pay rates with regard to industry as a whole, the company, the group, and the geographical area. Individuals should be compensated in proportion to their contribution to the general welfare of the company.

Compensation paid to research workers must be determined largely on the basis of personal judgment, but certain methods are helpful as guides to the administrators in exercising their judgment. It is important that each individual be considered as objectively as possible, and that all be considered under the same set of rules, i.e., that personal prejudices, likes and dislikes be eliminated. The methods of job evaluation and of merit rating are potentially useful in this connection. Starting rates, which are competitive, form the base of the salary structure. Although rate ranges for experienced personnel are more difficult to define, they can usually be delineated approximately for certain key jobs typical throughout the industry.

Administration by a group or committee probably has advantages over an arrangement whereby one individual carries all responsibility for initiating action and making decisions. Such a group should include at least one member who is close to, and therefore in a position to know intimately, the work of the individual whose salary is being determined. This implies that there be several administrative groups or committees. The time for granting merit increases and promotions should not be fixed by the calendar, but by the performance of the individual. On the other hand, the salary structure should be reviewed at regular and frequent intervals.

Practice in the matter of extra incentive payments to research personnel is not well defined. Where granted, payments are usually of one of two classes, discretionary bonuses or specific awards. The amount of the former is usually determined by the company's profit picture and the distribution decided on the basis of general attitude and efficiency of the potential recipients. The latter are granted to a relatively small number of individuals in recognition of a specific accomplishment.

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CHAPTER XIV

Personnel Policies and Personality Problems

In striving for satisfactory personnel relations with a group of rkers of any type, it is first essential to understand their psychol- y, that one may know:

1. What they expect.
2. What they resent.

nce this is a book on research management problems as distin- ished from general management problems, we need concern our- lves only with the special and occasionally unique psychological otives of research workers. It is assumed that the reader is famil- r with the psychology and handling of workers in general.

ndoctrination of New Employees [1, 2, 3, 4, 5, 6, 7, 8]

Because of their long experience and habits in acquiring knowl- dge, research workers are particularly fruitful subjects for careful ndoctrination programs. Also, because it is desired that they shall how business understanding, as well as scientific understanding with which it is presumed they are already equipped to start on heir job), a program suitable for research workers is different from hat for many other workers who must first be taught the grammar f their particular job.

It is presumed that a research worker is already prepared to unction on at least some of the technical portions of his job. His hief difficulty at the outset is usually not technical, but is com- pounded of the physical, social, and psychological adjustments involved in the transition from university to industry or from one

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This chapter by Warner Eustis, Director of Research, The Kendall Co.

industry to another. Here he needs an indoctrination program directed toward clearing away, as quickly as possible, the environmental difficulties of routine and personal acquaintance so that he may function. Proper housing is usually a collateral difficulty. Assistance on this point may be of primary importance, not only because of the creature comforts involved, but also because of the human ties and good will that can be created through helpfulness at the time of indoctrination.

Research workers place great value on suitable neighborhood sociability, availability of schools, music, theaters, lectures, and games for exercise. This evaluation should be taken as evidence of their discrimination as to life's best values and evidence of their desire to live and succeed in sound channels.

Training Program

As a part of the indoctrination period research workers will particularly profit by:

1. Having an organization chart which reaches at least as far as their own probable contacts, and preferably reaches from their own department to the heads of the company.
2. Being taken, as a new worker, around the laboratory and perhaps around the plant for the purpose of giving introductions to those whom he may need to know. This should include not only those having jurisdiction over him but also the heads of such departments as the library, stock room, mechanical shop; secretaries; and the management of laboratory departments where he may need to obtain contributory assistance, such as spectroscopic analyses, biological and analytical appraisals.
3. Thorough reading of all material collateral to their job.
4. Suitably escorted visits to manufacturing departments and, sometimes, by working for short periods in selected manufacturing departments and on jobs especially selected because of their instructive nature.

For purposes of familiarizing a new research employee with his field, it is often desirable to have him investigate the current manufacturing operations and to write them up in a report, which serves not only to familiarize the worker with his field but also quickly gives the research director an appraisal of the employee.

Many companies have an indoctrination book or a general laboratory manual giving the policies and often the procedures which are of direct interest to the research department. This is useful reading for the new employee, as well as for later reference on specific problems.

mployee Welfare and Services: Vacations, Leave for Illness, Personal Business, etc.

With regard to vacations there are special considerations which apply to research employees. In the first place, their productivity s not directly related to their hours of work, as with a machine worker, but more nearly resembles that of the executive worker in s emphasis upon mental activity. Since the production of a research worker places great emphasis on mental activity, a liberal acation policy is essential. Two weeks is generally considered a minimum, and some large organizations provide longer times, sabbatical travel periods, and the like. As with executives, some organizations permit and encourage extra leaves of absence—usually without pay—for study, travel, rest, and similar constructive activities which may seem desirable to the research worker. Most laboratories also provide sick leave on the same basis as for office and executive personnel. Since the laboratory hours and the thinking hours (and sometimes the business travel hours) of research employees are not confined to eight hours, but continue into evenings, Sundays, holidays, and vacations, considerable latitude is usually justified for personal business and all things which lead to a life of maximum breadth of outlook and success.

Insurance, Retirement, and Savings Plans

Where retirement funds are established for executive personnel, the research department is usually included. On all such matters the research department usually requires and receives no special provisions other than those customary with executive and office personnel.

Safety Committee

In many plants the safety committee covers all departments including the research premises. Often a research worker is a member of the committee. In large laboratories the great number of special risks often justify the existence of a separate safety committee.

Employee Privileges

The privileges granted to research employees are usually parallel to those accorded other employees of similar education and standing. Where there is no specially organized research department set apart by itself, as, for instance, when one or two research workers are directly connected with plant activities, ill-will is created if the established conventions of the environment are not followed. Usually such an employee would have the same vacation period as that accorded to the foremen or production executives with whom he is associated. Also, under such conditions, the employee would normally assume the same hours of labor.

PHOTO. 16. Testing an aircraft heater under the conditions of 40,000-foot altitude in the Cornell Aeronautical Laboratory altitude chamber. Sound policy calls for all possible precautions to protect personnel under hazardous conditions. (*Courtesy of the Cornell Aeronautical Laboratory.*)

Where a research department is separate from other departments, it may more properly establish rules of its own. If it is located at a point entirely removed from other operations of the company, even greater flexibility of action is possible and numerous special privileges appropriate to professional activities may be initiated without creation of ill-will.

There are two frequent difficulties with regard to the activities of the research people when they are closely associated with a production plant. The first concerns the use of time clocks and other formalities necessary for the handling of labor paid by the hour or day. Although from some points of view the reaction may not be rational, it will be found that research workers universally tend to resent time clocks or other regulations, if they are identical with those used for ordinary labor, unless the executives and general management are under the same regulations. The desired control of coming and going can usually be obtained by other means more suitable to the particular environment. For example, research men are usually happy to keep a daily diary of their activities, as well as a notebook. In a large, separately organized laboratory, in-and-out mechanisms are often acceptable which would not be acceptable were they directly transposed from use with day labor. With regard to the use of their time, research workers, in general, consider that they are on their honor. If they abuse the privilege they expect, over the long period, appropriately radical reaction.

The second point which often raises difficulty is regularity of hours. It is obvious that for the personal welfare of the research worker, as well as that of his co-workers, he should, in general, keep regular hours. Research workers on important jobs, however, are often required to sit up all night in order to take readings, or to complete an experiment; or it may be necessary for them to give speeches or to travel for special purposes. Appropriate flexibility for maintenance of health and mental acuity is necessary for people who are, by the nature of their work, required to maintain irregular working hours.

It should not be inferred from these remarks that sound habits of personal regularity are any less important to the research worker as a person, or to his laboratory, than in other pursuits; nor is there justification for more latitude or less businesslike relations. It is merely that businesslike relations and procedures are, of necessity, more flexible and more dependent upon the conscientious interest of the worker and less upon compulsion and rigid rules.

If the initiative and productivity of the worker suffer under freedom so that he loses momentum, inflexibility is not the device to stimulate interest and productivity. If a research worker will not carry his load voluntarily, the rules should not be tightened at the expense of the over-all productivity of the group, but the dilettante should be dropped.

Employee Social Organizations and Activities: Official Cognizance

The development of employee social organizations and activities is naturally dependent upon the size of the research group. In very small groups, such organization is impossible. Any participation in social organizations must be with other departments of the business. When, however, a research organization becomes larger, or when it moves into special quarters removed from manufacturing or sales, it may, depending upon the circumstances, become highly organized socially.

Recognition of the benefits to be obtained by reasonable social organization among research workers is general with modern management, although the scope of the organization depends more upon the size of the group than upon the interest of the corporation.

By way of comment we should add that official cognizance of social activities and their stimulation should not be artificial. The sustaining power and demand for the social events should be spontaneous with the workers. The company itself usually should not undertake more than a helpfully constructive attitude. It is probably quite as wrong for the company to bear the brunt of the expense as it is for the company to be unco-operative or unwilling to take nominal and appropriate steps to assist the normal social impulses of the group. It cannot be too strongly stated that artificial propagation of social activity will create a counteraction which is much more destructive than inadequate assistance. A feeling of fraternity and group solidarity can be gently encouraged, but cannot be directly impressed from above.

In connection with the social activities of larger organizations it may prove desirable to provide a part or whole-time paid organizer or to assign the task to someone in the organization, because otherwise there would be a tendency for unprofitable detail to fall upon a person who is usually elected to leadership because of his power and scientific pre-eminence.

Provision of Facilities and Types of Activity

Some large organizations provide clubs and golf links for the research workers, or for the research workers in combination with others, usually at a very moderate fee. The formation of tennis clubs is relatively common, although actual ownership of courts is not frequent except in the largest organizations. Tennis and golf teams often play competitively with other teams in the company or teams from other companies or clubs. Bowling is another sport which is often organized on a social basis.

Also, card parties, dramatic clubs, musical clubs, chess, dances, and week-end skiing parties (in some northern organizations) are popular, the latter particularly among the younger men and their wives, but also among an increasing number of middle-aged employees who have practiced skiing for some years. Other social activities are periodic teas or theater parties which may include the youngsters.

Employer-Employee Agreements

Both the negotiation and the substance of agreements between employer and employee are of highest importance in establishing sound relations. With research employees, while there may be a separate employment contract, there is almost universal use of a joint patent agreement with employment as the consideration for signing the contract. Where a separate employment contract is concerned, the questions involved are not peculiar to research and, hence, need not be considered here.

In some cases, a research worker brings to his new employer a patent or patents, or perhaps a going business with patents. These are specialized problems which depend on the desires of both parties and upon the already created values and investment which exist at the time of negotiation. In general, however, it may be said that arrangements should be such that separate remuneration for patents and for services should be established in a form so that employment may cease without thereby creating unfair or unworkable patent relations.

On the other hand, most researchers enter the employ of a new company without owning patents which they desire to sell or develop. If they have taken out patents, their status is already clearly established by assignment or license. Generally the new employment relation involves only the future, in which case all that is necessary is the standard, routine contract used informally with all research workers of the employer. Some of the more important aspects of such a uniform research worker's contract are:

1. A list of all patents issued, pending, or contemplated on work done prior to the present employment, with a simple, clear statement

of their status in relation to the present employment, if any. If there is no relation, this should also be so stated.

2. An agreement to assign to the employer all patents taken out upon work done at the request of the employer, or within the present or contemplated scope of the employer's activity, and which are conceived during the period of employment. All expenses of such legal work are customarily carried by the employer and the employee agrees to sign all needed papers and to assist at any time.

3. A clause forbidding speeches, publication, or disclosure of facts about the employee's work or the employee's business without formal approval in each instance.

4. An agreement is included in some such contracts that if the employee leaves for other emplovment he shall not, for a period of time, be engaged in the same business or in work upon the same products, as in the prior employment. This provision is less than customary and has been the subject of abuse by employers. The courts generally frown upon anything which prevents a man from freely using his profession or skill for gainful employment; but they also frown upon any action involving other than highest ethics on the part of a research employee who changes employment to a competitor. Where a man sells a business and patents and perhaps also acquires emplovment as a part of such sale, the courts usually support provisions which prevent the employee from entering the same business for a period of years.

Certain over-all remarks may be of value to both the employer and the research employee in establishing a background of mutual respect and good relations. The employer, in asking an employee to sign a patent employment contract, has a great advantage over the employee. This arises because the employee is anxious for employment in order to live, and because he usually does not understand his rights. If the contract is a uniform contract, the pressure is very great because of precedent. Employees, particularly, fear the danger of raising questions about their own integrity of purpose if they question a contract. This throws a heavy moral responsibility on the employer. In discharging this responsibility, the employer may help by:

1. Always presenting the contract for signature when employment starts, not afterward.

2. Explaining orally what is covered when the contract is presented for consideration and signature.

3. Providing a duplicate for the employee to retain.

4. Having nothing in the contract to which the employee can be advised to object, if he gets legal advice before signing. It should be considered that if an employee has resigned a prior position and perhaps has moved his dwelling or has otherwise pledged himself mentally and morally to a new position, then to present an overreaching contract (however many other employees may have signed) can only be classed

as taking an unfair advantage, and will create unsound employee relations. Under these conditions, the employee is entitled to full latitude of objection and alterations, and the employer is morally under highest compulsion to make the alterations desired. Emphasis upon these points does not usually arise from intentional unfairness on the part of the employer, but from the fact that the document has usually been prepared by a lawyer at the request of the company. There being absent the balance achieved by the meeting of minds of two parties, many lawyers will seek only to protect the rights of the employer. The result of this background of preparation is often a unilateral document, prepared so as to catch the occasional, unfair research employee, but which is concomitantly unfair to the freedom of the average, fairminded employee.

The Woman Worker as a Special Problem

With the increasing numbers of women taking their places in the research field, the question of the woman worker as a special problem deserves attention, mainly because it gives one pause to wonder just how much of a "special problem" she now is. True enough it was only a short time ago that women were definitely pioneers for their sex in all fields of human endeavor; and in those earlier days the woman worker was a problem. But the wider scope of activity, opened by higher education in practical application of knowledge for women, has brought a definite change and an acceptance of women in the vast majority of cases.

Because of this acceptance of the woman worker—and in very many cases, because of the desirability of a woman worker in certain positions—it is well to consider just wherein she differs in her ability to command a place in business or professional life.

There would seem to be one major and inescapable obstacle. It is a factor which has always been recognized by the employer in hiring a woman—and it will always have to be so recognized. Women, by and large, do not combine a career and homemaking and give equally of their best to each. And if the opportunity for marriage presents itself, in the majority of cases, the woman will relinquish her career, no matter how much education or responsibility she has achieved. Thus there is created an extra hazard in hiring the young girl scientists, since there is usually the expectation that their stay will not be long; that efforts toward their further education in science and business are not justified because the investment will be lost; that efforts to give major responsibility with commensurate pay are much less rewarding than with young men. From day to day, a young woman must be engaged on the basis of her current value and much less on the basis of her long-time potentialities.

Another obstacle in the path of hiring a woman worker might be the fact that frequently women have more initial difficulty in adjusting themselves readily to being moved from one locality to another. A woman may do a very fine job in a locality where she has been living for a long period of time, but, upon being transferred to another part of the country—even if on the same type of work, within the same company—may do a much poorer job, partly because the problem of adjustment is more dependent upon social convention than in the case of a man. This obstacle, however, may well disappear in time, especially in view of the changed attitude of women brought about by their advent in the armed forces, which has, of necessity, trained them to accept a change of locality without having it affect their competence.

In any case, a little extra care and thoughtfulness during the indoctrination period will be found rewarding. These social obstacles are also operative in creating a condition where women in business or scientific matters are found not to move forward with the breadth of vision and the will to succeed which is characteristic of men with similar mental endowment and education. Thus, they seem to solve with ease problems which are placed within their range by social convention, but they largely fail where many people, in diverse places, must be persuaded or contacted in order to get their acquiescence or their knowledge. Dissatisfaction on these points among research directors largely arises from a failure to recognize the social necessities and boundaries of the time. Women cannot do the impossible any more than men, because, even if they have the courage to create new boundaries of action, men are slow to give ground. Men themselves are an obstacle to full expression by women of their abilities. Thus, numerous problems of a research director in utilization of women lie in the failure to understand what is impossible, what is fair, what boundaries men themselves place on the fields open to women.

A third difference between the woman worker and the man worker, particularly noticeable in the research field, is that, in general, the woman excels in detail work—compiling data, correlating facts, measuring minutiae, laboratory testing—but she frequently lacks the business, promotional point of view. Here again, however, this generalization is slowly becoming less true and women, through the greatly widened horizons which carefully planned educational courses have brought, are gaining in vision and developing their imaginations with more of an eye toward the objective than the subjective in every field.

Occasionally, there are women who run complicated and large businesses with complete success in both executive and promotional phases and, equally rarely, there are women scientists who have promotional courage, judgment, and power to succeed which would not be excelled by any man. Research problems involving the development of products especially for women or infants, such as clothing, hats, infants' wear, sanitary devices, and hospital testing of biological samples are special opportunities for women, in which they have conclusive superiority over men.

Since, as we have pointed out, attitudes and visions on the part of the woman worker are changing and slowly evolving, thus helping her more and more to fit into the pattern of the economic and social necessities of a business or professional life, it would seem that she is becoming increasingly less a "special problem." There is, to be sure, the important, major obstacle of a career versus marriage, or perhaps continued work after marriage, with the attendant divided interest, and that obstacle is one that is not likely to change essentially. Except for that, however, there is reason to expect that through education and increased experience in the office and laboratory, and with guidance and inspiration on the part of research executives, the woman research worker may, over the years, be increasingly recognized as an effective force in industrial research.

A few detailed problems may well be mentioned. When a laboratory is in a manufacturing building, it has long been customary to provide the research department with special washroom facilities separate from those used by factory hands.

With the employment of any considerable number of women scientists, a female personnel representative quickly becomes essential either as a part of the research group or as a member of the regular personnel department of a plant to take over disciplinary and social problems. In handling such problems themselves, men are at a great disadvantage and rarely are able to maintain relations with a clarity and fairness satisfactory either to themselves or to the women concerned. On other matters involving the scientific work itself, women should deal directly with their associates of either sex on a basis of normal equality.

At least for purposes of indoctrination, many research directors find it best not to give full responsibility to a new woman worker immediately or as quickly as to a man. Much success has been had in adding a woman to assist a man, but not a group. The results of such an arrangement appear in rather quick and decisive approval or disapproval by both parties. Often the result is much more durable and productive than the adding of a restless young man, impatient for research independence, would have been. A woman is more inclined to evaluate the job on the basis of her success in the work than in her pride of independent power.

Sometimes able men have such objective and dominant personalities that male assistants refuse to work with them for long periods. It often proves a fact that such a man can be assisted by one or more women with very satisfactory results.

Where research requires a large amount of skillful, accurate testing, such as spectroscopy, photography, microscopic appraisals, multiple extractions or reactions, a woman scientific worker is far to be desired over a man.

These illustrations and many others are to be found through careful appraisal and experimentation by the research director in the field of human adaptability and tastes. The mastery of these factors should prove fully as interesting and demanding of skill as exploration of physical science.

Personality Problems

Among research workers, personality problems are perhaps no more frequent and no more difficult than among mankind in general, although they may have some special aspects. In approaching a solution to such a problem it is perhaps worth while to decide whether it merits an attempt at correction or whether pruning is more efficient. With research workers this decision is often more difficult to make than among other classes because research requires genius. Genius, by definition, is unusual or non-normal; so the very search for genius is also a search for non-conforming or individualistic personalities with impulses and opinions, dreams and ambitions which may confuse or repel the more normal associates.

Creative Work Requires Genius

It is, however, well recognized that great creative work does require genius. Consequently, if the results of genius are desired, the environment—of which the management is perhaps the most important element—must be friendly, appreciative and fully responsive, not just tolerant. If these personality problems arise from true genius, the task of management is to accept them as a welcome challenge to the skill of management; but if the problems arise with a person who does not bring compensating values, then a decision that the task is not worth while should be easy and severance the solution.

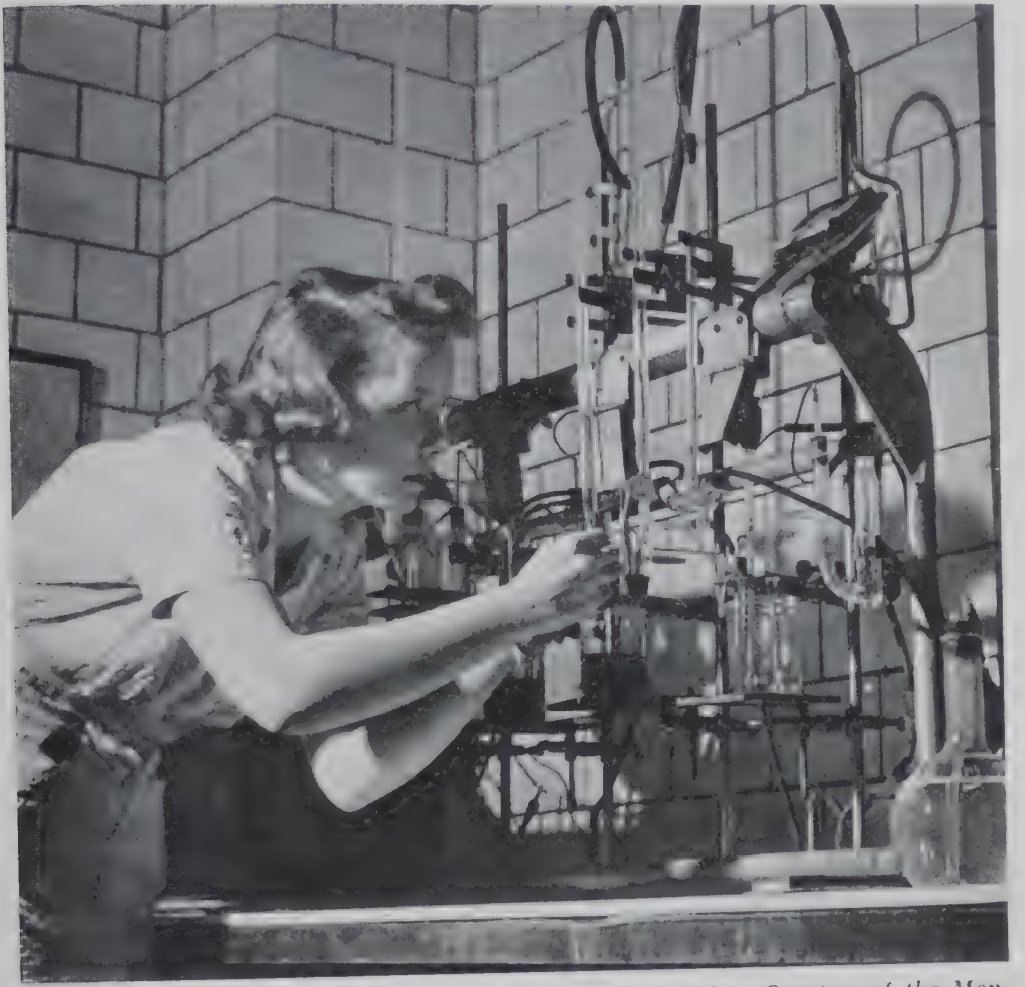

PHOTO. 17. Women excel in many types of laboratory work. *(Courtesy of the Monsanto Chemical Company.)*

Separate Laboratories versus Group Space

Research is fortunate that there are numerous practical, mechanical steps which will supplement patience and human understanding and good fellowship on the part of the research leadership. For example, men may often be placed in separate rooms for such purposes as quiet, freedom from unnecessary talk, prevention of petty inconveniences such as vibration, drafts, odors, corrosive gases, and other special interferences.

Sharing Apparatus

With many research workers there are special difficulties in sharing apparatus. The objective, fast worker is very impatient of waiting for facilities. His time is expensive and he has a mental characteristic known as the "heat of the chase." While it endures, a man is creative; when it cools he is listless and rapidly becomes relatively unproductive and unstable. Many personality difficulties may be alleviated or, indeed, cured by private apparatus.

A Desk and Chair

In connection with the desirability of private space there is almost universal need for a good desk and chair for master research workers. The former conception that desks and chairs are bad for research arises from the notion, which may be correct with production workers, that sitting down means nothing is being done. In research this usually applies only to technicians and workers on repetitive testing. For a man who alternately thinks, then works, then thinks, the lack of a chair and some seclusion to think and read, as well as good work space, are environmental limitations which lower his efficiency. Briefly stated, where his environment does not fit his mental pattern, acute personality difficulties will generally appear in men who are conceded, by all their associates, to be potentially productive and desirable.

Mental Attitude of Personal Research Assistants

Speaking again of personality difficulties, an assistant of the "following" type will often alleviate them while, on the contrary, a different assistant will sometimes cause or aggravate them. Some men want to be left alone; others want company, but not too aggressive an assistant.

Personality Difficulties Arising from Omnipotent Judgment

A common source of personality difficulties among research workers lies in research directors or section leaders who behave as if they possessed omnipotent judgment. In the competence born of years, they express their knowledge with assurance, but should they fail to convince the imaginative, creative, inexperienced minds, a sense of antagonism and frustration may form to build what are later classed as incurable personality defects. If, under such conditions, a man is moved promptly to a more openminded and congenial environment, he may meet with great success; if left to his own devices, he may become a failure because of a strength wrongly classified as a personality defect.

Research Directors Also Have Personality Defects

If a research worker of unquestioned ability exhibits increasing personality difficulty without a clearly discernible cause, and if it is known that his home life is normal, then the research director should properly analyze his own personality defects and those of his section leader, and question his own powers of leadership and management. The fact that a majority of one's associates are not upset does not prove that they do not have to put up with a lot and make plenty of allowances for their superiors. Good management does not include making over the fundamental nature of its workers; it lies in their utilization. Personality difficulties are evidence of strain and frustration. If the frustration can be removed the personality may be expected to improve.

Frustration Among Aggressive Workers

Another frequent cause of acute personality difficulties arises from the drive which characterizes the most productive research workers. Some men do not push and try to sell ideas; hence, they cause little friction. On the contrary, some of the ablest men struggle so for rapid achievement and are so largely objective in the effort that they fail to perceive the effects of their efforts upon their environment. When a highly aggressive individual encounters an obstacle in the form of a personality he brushes around it; or, if that is impossible, he tries to fight his way straight through. If he succeeds, he rushes ahead on his job, oblivious to scars he may have caused. If he is unable to progress, he will fight, then turn aside with a sense of disgust and frustration.

Selection of Suitable Problems for Each Worker

Yet another cause or aggravation of so-called personality difficulties lies in the selection of problems for the worker. The highly productive worker produces because enthusiasm supports his effort. Restrained rebellion arises, with outward irritations, when a man is forced to do work that does not interest him. A laborer quits under such conditions, but the better research worker tries to hide boredom, perhaps vents his resentment at home, and slowly drifts into a circle of unproductiveness and irritability. Thus it may be said that the selection of suitable tasks, for the skill and tastes of the worker, is a primary objective in controlling incipient personality difficulties.

The Remaining Few Irreconcilables

In fairness to management it must, however, be recognized that there are rare, unfortunate individuals who do not try or cannot succeed in subduing their idiosyncrasies, no matter how tolerant their associates may be. If these few cannot be isolated to the necessary degree, their is a sad lot and beyond the power of intelligent management to help.

Summary: Human Relations and the Maintenance of Morale as the Main Objectives

A research worker is an educated man. He considers himself to be of professional status and accepts freely the customs, obligations, and privileges of educated men. Like other human beings, he naturally and properly resents anything which tends to place him in some other class than where he belongs. He accepts as his own duty and his own right, the behavior pattern of his class. For example, professional men do not, as a rule, willingly join a union or accept the leadership of labor; and conversely, the research worker's ideas are not readily accepted by labor. While having in common the natural motives of all mankind, each has his pattern of action and preference. Trouble comes quickly when there is confusion of thinking about personnel. Failure on the part of management to understand the expectations of workers is the greatest single cause of discontent and labor inefficiency among research workers. It will be found that if motives are understood they will usually be found reasonable. The unreasonable aspects which appear will be largely the outgrowth of irritation arising from failure to recognize the primary motive. While this is true of all human beings, it is especially true of research workers, who, because of their refinement, their educational attainments, and their training in rational thinking, are relatively more fair, conscientious, conservative, and rational than most other groups can hope to be if they have had less training in history, ethics, sociology, government, and the other humanities.

PHOTO. 18. Attractive lunch rooms are a factor in maintaining employee morale. (*Courtesy of the Radio Corporation of America.*)

As a concomitant of this training and of the belief that they have a right to form opinions on a variety of subjects, it is difficult to "talk down" the research worker. Facts may be used, but the worker will still feel he has a right to his opinion if not convinced by the facts. With some research workers and some leaders this may create tense situations and sharp differences, which, if not kept on a plane of high mutual respect and courtesy, may result in personal animosities which are much more intense and more destructive than among ordinary workers on jobs where teamwork and close collaboration are less essential. It is often difficult for the head of a large company or for a research director to realize that his research workers view him as an intellectual and social equal, and not as a superior except in corporate authority and length of business experience. Indeed, with respect to scientific training, they may rightly view him as an inferior.

Thus it becomes apparent that freedom and latitude of action should be gauged, so far as possible, to the needs of the worker. If a man can carry responsibility, or can move rapidly and broadly, every reasonable effort should be made to let him use his full power.

It is not within the proper scope of this chapter to discuss the responsibilities of research workers or the definitions and boundaries of research problems. It is important at this point, however, to call attention to the profound effect, on the morale of the good research man, of any lack of clarity and understanding in these matters. The effective research man is essentially conscientious and often meticulous. A clear understanding in his own mind of his assignment and his duties is necessary not only to his performance, but to his sense of accomplishment.

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CHAPTER XV

Professional Growth of the Research Man

Importance of the Research Man to Industry

The research man now occupies as important a place as the production man and salesman in the organization of industrial corporations and companies. Without adequate attention to the professional growth of its research men, a corporation will find itself unable to contend with competition. It is upon its research workers that an organization must rely for new products and improved old ones. Not only must a company have these, but the improvements and the new products must be of high quality for the organization to prosper. It is here that industry feels the full weight of the importance of the development of its research men.

Men whose professional growth has been retarded will not be able to produce ideas and applications capable of meeting modern competition. The output of organizations whose research workers have full opportunity to grow professionally and avail themselves of it, will reach the market first and usually be superior. There is no substitute for imagination and resourcefulness, which are the basis of creative thinking. These flourish only when the investigator has ample opportunity for developing. Research men who were stunted in their professional growth never could have developed radio to its present status. They would not have realized the significance of their findings. These results actually were obtained in the process of conducting an intensive investigation upon electrical communication.

The importance of the research man to industry was not always recognized. Just thirty-five years ago there were few industrial re-

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search laboratories; now there are over three thousand. The number of scientists engaged by industry has increased as radically. There are now over 100,000 men engaged in the pursuit of new knowledge which will make new things possible. This constitutes a sizable group. It is a major responsibility and should be a major activity of industry to provide these men with the proper guidance and encouragement for the attainment of their full professional growth.

Both industry and the public now realize the importance of granting the potentially successful inventor or scientist all the opportunity and encouragement possible. Thanks to this attitude the modern research worker need not suffer the experiences of Charles Goodyear. If the full opportunity to develop all his ideas had been available, he might have added more to man's knowledge than his process of vulcanization. Unfortunately, as an unsuccessful inventor he was not encouraged and spent many years in debtors' prisons before he attained recognition.

Without the research man, industry will not progress; it will merely stumble along. Perhaps at times the stumbling will be in the right direction, but with the aid of properly developed research men industry can exceed its record of the past.

The Necessity for Cognizance of the Latest Developments

A doctor who is not aware of the most recent developments in medicine, both in drugs and techniques, cannot practice his profession to the greatest benefit of his patients. It is necessary that he know the latest advances. The same holds true for the research worker. He not only must be thoroughly familiar with the facts that have accumulated through the ages in his own particular field of work, but must keep abreast of the newest developments.

The means whereby the individual can accomplish this are many and varied. There are the commercial periodicals dealing with his particular field and related fields, in addition to the publications of the various professional societies. The meetings of these societies frequently provide further advanced information in the form of papers, reports, and lectures. Government publications and releases and information in the form of reports and translations by the armed forces of our nation are at present an invaluable source of knowledge. A properly organized library in industrial laboratories forms an excellent source for the various reports, papers, and other publications which have been mentioned. Such a library is not only a repository of information but a working center which compiles and distributes information. This may be done by means of bibliographies, indices, and forwarding of articles of interest to men who have shown interest in the subject matter. It is not sufficient that the research man keep in touch merely with his own specific field. It is well also to follow related fields, for often the really important contributions are made when rather distinct and separate branches of science can be made to function together.

The problems presented to the investigator are quite diversified. Fundamentally the problem may be finding uses for a new chemical product, or a new electrical device; finding new uses for something old; improving old processes; devising new products; or harnessing a natural force in a new way.

Industrial research laboratories are usually primarily concerned with applying available fundamental knowledge. The successful industrial applications of new knowledge can come only through the efforts of versatile, well-grounded, well-informed scientists.

Here are some of the major research problems which may be of great interest in future industrial research:

1. Photosynthesis. Despite the efforts expended to date, it is still a prime target of research.
2. The application of atomic energy to peacetime uses.
3. A feasible solution to the aerodynamic problem of passing safely through the area of transonic speed.
4. A cure for cancer.

A research man who has not kept up with the advances in broad fields cannot expect to cope successfully with such problems as these. They show the interrelationship of various fields of science. Not one of them can be solved with the knowledge of one field alone. It is of prime importance to both the individual and industry that the research man continually grow professionally and be alert to the constant advances of his science. Industries which do not encourage and aid their men in this direction can hardly obtain the full benefit of the research men they employ.

Personal Characteristics and Their Importance

The growth of the young man entering upon a research career will depend upon his characteristics and ability for *self-develop-*

ment, as well as the facilities, opportunities, and encouragement o fered by the company.

Consideration of the essential qualifications for a successful research worker and his driving motives or urges will help in establishing a clear understanding of the requirements for his health professional growth in the company organization.

One essential qualification for a scientific research worker is persistent intellectual curiosity coupled with an aptitude for, a well as a thorough training in, the use of the scientific method o hypothesis, experimentation, and conclusion. The will to emplo this qualification in productive activity is the creative urge tha must underlie in some measure the efforts of every true researc worker. Other normal human urges are invariably present to a extent dependent on the individual's personality. Some of the mor important ones of these are (1) the desire for wealth, (2) the esteem of one's colleagues, (3) the desire for fame and prestige, (4) the desire for power, (5) the desire to help others or humanity at large

That research man whose work environment allows the maximum opportunity for satisfaction of the particular motives or urges which dominate his personality will generally attain the greatest professional growth consistent with his capabilities; and the direction of such growth will of course be determined by the nature of his dominant motives.

Ideally, perhaps, the creative urge may not be directed even by the individual worker himself, except in so indirect a fashion as to be impractical for anything but basic research along the line of a "natural bent." In pure basic research the discovery of new facts that help push out the ever-receding frontiers of man's knowledge of his world is a complete and sufficient end in itself.

More practically, in industrial research, compromise must be made to fulfill the employer-employee contract. This is the responsibility and obligation the industrial research worker assumes and he must bend every effort to carry it out to the fullest extent. A wide field of industrial research work is open to him and a considerable leeway for trial and error is usually available.

The company, on the other hand, should make every effort to place each individual research man in a position where the greatest opportunity will be afforded him to satisfy the particular urges that make him a well-adapted worker capable of growth into the position best suiting his capabilities. The discovery of this position is the responsibility of both the director of research and the individual concerned.

The value of the best basic training is acknowledged by the scholarships, fellowships, and financial aid for research given to many colleges and universities by industry. Also, many young men have been given financial assistance and leaves of absence by industry to return to universities for doctorate or postdoctorate training.

Personal characteristics will influence the growth of the research man, perhaps more than technical ability. The introvert, or lone worker, will probably be of most value in scientific research, or applied research, by building up, gradually, through his own efforts, a series of important patents. The extrovert will probably become a group leader and grow into a position requiring ability to handle men and to direct technical work.

By nature, a research man must never be satisfied with things as they are. Once he becomes satisfied, progress and improvement cease. He obtains satisfaction from the contributions he makes to progress.

Habitually, the investigator must question, evaluate, and weigh everything he hears or sees. Otherwise, he may overlook important links in a chain of observations or important possibilities not directly connected with the problem immediately at hand.

He must have a broad point of view to achieve the maximum results from his investigations. Keen powers of observation are necessary to grasp all of the facts brought out by experimentation, as well as the breadth of vision to apply these facts to the utmost. Frequently two individuals will be working on the same problem, and each will reach a satisfactory conclusion. One, however, will have made many observations during the progress of the work, which will enable him to continue far beyond the original scope of the problem to make unexpected and valuable discoveries. The other will simply carry the assigned work to a successful conclusion.

The individual must not be over-awed or bound by tradition, custom, or established practice. That an operation has "always" been performed in a certain way is no grounds for considering that way to be the "best" way. For example, man could observe in nature that, for traveling on land, two legs or four were used. Had he been bound by this practice, the uses of the wheel never would have been discovered. Likewise, man could observe in nature that wings that flap seemed necessary to flight. Attempts to copy this procedure were disastrous. It was only when man broke away from the flapping-wing principle and brought forth something different that the airplane was developed.

A research man who is working to establish himself can learn much in his contacts with more experienced men who are willing to offer advice and assistance. A young man also can learn much from workmen in plants and shops. This group has a familiarity with details of machines and processes which can be put to good use by a research worker who can recognize native intelligence and operational skill. On the other hand, an over-zealous effort to establish himself as an "expert" in the eyes of workmen can put a research worker in a ridiculous position very quickly.

Personality can be improved and character broadened, if the worker is encouraged to take an active interest in the civic clubs and civic activities of his community. Personal contact with others who are in diversified fields of endeavor will tend to broaden his viewpoint, and to round out the development that is taking place along other lines.

It is obvious that the professional growth of the research man depends not only upon himself, but also upon the attitude of the company and the character of environment and opportunities which the company provides. Each individual has his own personal characteristics and must endeavor to use them to the best advantage both to himself and his employer. The company must be ready to recognize properly the self-development of the young research worker into an individual of importance if the company is to receive the maximum profits from its research expenditures.

Publication of Research Results

The self-development of a college graduate into a valuable research worker involves, among other things, the development of hi professional prestige. This is of value to both the individual and the company. He should be encouraged to meet and to know investigators in the laboratories of other companies.

It is not uncommon for men from different research laboratorie to get together and discuss recent advances in science or problems o mutual interest. This also gives an opportunity to see the physica equipment of other laboratories. Both recognition and encouragement should be given by the company to the individual for any effort to increase the latter's personal prestige, personal contacts, and personal knowledge. Some companies are best known for the caliber of men in their research laboratory, and the personal prestige of the individual accrues to the credit of the company.

The worker should be allowed to publish and discuss the results of his researches and be trusted not to disclose any information which should be, at least temporarily, kept secret. This not only allows the man to grow in stature but also brings about a better understanding by the public of what industrial research is and how it benefits mankind. Dr. C. F. Kettering, formerly Vice President in Charge of Research of the General Motors Corporation, once said, "When you lock the laboratory door, you lock out more than you lock in."

Publication can be achieved by means of company facilities, through the medium of professional societies, commercial periodicals, or direct publication by the author for public consumption. We mentioned before that these are the means whereby a young man can keep himself abreast of the latest developments in his art. It stands to reason that the reverse also holds true. It is by these means that a young man can make public his own contributions to the advancement of his art, and it is necessary for his full professional growth that he do so. The reputation of the organization whose research men do publish their findings will be enhanced according to the caliber of the work done.

Publishing will also bring about an interchange of ideas with other men or groups in similar work and may lead to new investigations, developments, or products which otherwise might remain hidden. As an example, let us assume that John A. Mathews had never published the results of his metallurgical research which brought about the development of high-speed and non-corrosive steels. The status of this nation as the greatest industrial power would have been postponed until someone else published similar findings. The automobile would cost several times its present price were it not for the hard high-speed steels which make possible stamping, cutting, and other processes in large-scale production. Pumps in mines where the water is exceedingly corrosive would have a very short life without stainless steel.

In the field of science and industrial research there are, for various reasons, facts which cannot be published, but this condition is usually temporary.

Naturally, both individuals and companies wish to protect themselves by means of patents before making any patentable results public. The research man should, for his own protection and for that of his firm, make sure that a patent has been applied for, if justified, before the results of his investigation are made public.

The Role of the University Research Centers and Research Institutes

With the growing importance of research in industry, the colleges and universities of the country recognized the role they might play in assisting in research programs. The vast facilities of these institutions, although primarily devoted to education, can be used to excellent advantages in research problems to the benefit of industry, education, and the development of the research man. In view of the fact that so many problems involve the application of various branches of science, the solution is dependent upon the combined knowledge and work of a group rather than of an individual. Actually the old organization of a department head with several assistants has given way to a research team. This team is composed of men who are specialists in the respective fields concerned in the problem to be studied. This holds true in both universities and industry, and necessitates that the research worker advance in stature and knowledge as much as possible.

The university research center aids in professional growth in several ways. It provides a source of knowledge in many fields and authorities in these fields who may be contacted if the need for information in a specific field is evident. The opportunity for the individual to contribute to knowledge by the interchange of ideas and thoughts with these authorities in the fields of pure and applied science offers an excellent chance to the research man to improve not only his knowledge but his professional stature. Usually courses or seminars are available to the individual which will be of great interest and value to him in his work and will aid his development. In addition, it is possible for him to contribute to the professional growth of other men by giving lectures or courses at these centers. Fellowships are offered to promising scientists by many of these centers so that they may pursue their investigations and have the universities' tremendous facilities available to them.

As an example, the Mellon Institute of Industrial Research provides the resources for investigations in many fields. These researches are conducted on a fellowship basis and offer the research man a great opportunity to advance himself professionally. These fellowships are sponsored by industrial concerns interested in specific problems. Typical ones offered to the scientists, the industrial firms which sponsor them, and the problems involved are: International Nickel Company, research on nickel derivatives; Corning Glass Works and Dow Corning Corporation, research on new silicone resins; National Lead Company, research on magnesium; Koppers Company, research on gas by-products and gas purification.

Many other institutes function in the same manner. The Armour Research Foundation, under the sponsorship of industrial concerns, conducts investigations on subjects covering eight major divisions: physics, metallurgy and minerals, chemistry and chemical engineering, mechanics of solids, electrical engineering, engine research, fluid mechanics, and thermodynamics. Battelle Memorial Institute operates in a similar fashion. In addition, there are highly specialized research organizations such as the Institutes for Pulp and Paper Research, for High Polymer Research, and for Textile Research which offer the investigator opportunity to aid his own development. He is responsible for his own development and can accomplish this by taking advantage of the fellowships offered, the courses and seminars available, the opportunity for contributing by lectures, for consulting with authorities in various fields and exchanging ideas with them.

In many cases the fellowships available are open not only to men who are not yet employed in industry but to those who already are. The latter are released by their employers to accept these fellowships. This is frequently done by industry. Men who have worked on fellowships sponsored by industrial concerns often have the opportunity upon completion of their work to continue as a member of the research staff of the concerns involved.

Whenever possible, industry should encourage its men to avail themselves of the opportunities afforded by such institutes. Any feasible method by which scientists can increase their professional stature should be recognized by industry as something which will benefit the employer through the increased value of his men.

Industrial Research Laboratories

There are many excellent and well-equipped industrial research laboratories in existence. It now seems incredible that at the beginning of the century organized scientific research in industry was virtually unknown. The benefits accrued to mankind, to industry, and to the individual research worker since then have been multitudinous.

Many industrial laboratories underwrite in part or full the cost incurred by their research men in taking further studies which will add to their knowledge and aid their professional growth. In addition, many such laboratories organize courses of study and seminars conducted by staff members on subjects of interest and value to their personnel. Many concerns make it a policy to send their men to professional conventions throughout the nation not only so the industries involved may be represented but so their scientists may personally make their own contributions to such meetings and have contact with other men in their fields. Industrial laboratories do in many cases offer their men the opportunity to investigate subjects basically of interest to the individual. The value of such a practice can readily be seen by examining some of Dr. Irving Langmuir's work.

At the General Electric Laboratories in Schenectady, New York, Dr. Langmuir investigated chemical reactions at low pressures purely as an item of interest. Nearly three years were spent on this work before any real application of it was made. The application brought about the first argon-filled incandescent lamps which now save the American public about a million dollars a night on its lighting bill.

In 1937 the Westinghouse Electric and Manufacturing Company announced its plan to sponsor ten research physicists to explore the fields of pure science, thereby accelerating scientific progress. These men, known as Westinghouse Research Fellows, were chosen from the ranks of those having the equivalent of a doctor's degree in physics, chemical physics, or physical metallurgy and were all under thirty-five years of age. Dr. E. V. Condon, under whose direction the investigations were started, stated at the time: "Each widening of the horizon opens up new possibilities of technical advance although it is not usually clear at first what these possibilities may be. Past experience has shown that nearly all discoveries in pure science have sooner or later been of value."

It is to the credit and benefit of industry that it provides scientists the opportunity for professional growth. The research man should not neglect such means of developing himself. No company should lose sight of the fact that research is its life blood, and the development of its professional men is of prime importance to the quality of that blood.

Ways in Which the Company Can Aid the Development of the Research Man

If industry now recognizes research as the best insurance for existence and future growth, the company employing a research worker is probably wise to provide every feasible facility and give every encouragement necessary for the growth of that individual in the field of science—pure and applied.

Certain requisites are essential to the development of a research man to his fullest capacity. Probably the most important consideration is a salary sufficiently large to relieve the worker from financial worries in order that he may devote his time, energy, and thought to his profession and not to monetary problems. If a research worker is to become truly proficient, he must feel that his contributions to either practical or fundamental science are appreciated. This appreciation can be shown in various ways: by placing the man in a more responsible position; by providing some assistance in order that the time of the trained scientists shall not be consumed in routine work, or in tasks that could be performed by a less highly trained worker; by some type of bonus as a reward for the development and completion of a difficult problem or invention; or by the publication of his work.

Training programs within the company itself should be instituted whenever possible. Members of the staff should be encouraged to prepare and deliver lectures in their particular field. Visiting lecturers should be invited and, when possible, the audience should comprise members of the research staff of different companies. Such programs allow the man to become familiar with the work being done in other branches of the laboratory and in other companies, and grant him the opportunity to know his colleagues and the type of work they do. They also act as a stimulus for the man's own work.

It is important that the individual have the freedom to discuss his work with his associates. The work of Dr. Edwin H. Armstrong, discoverer of the principles of superheterodyne and superregeneration, offers us an example of this. He has stated:

> The fact that is the first step in the chain of events that was to lead to the superheterodyne invention came about because I could not understand the mathematics used in the dispute he has referred to, and I had to make a long experimental investigation to clear it up. This investigation gave me for the first time a clear understanding of the nature of the heterodyne.[1]

In this speech Dr. Armstrong was referring to a dispute mentioned in his introduction by Alan Hazeltine. The dispute was on amplification due to heterodyne reception and was occasioned by a discussion he had regarding his work. In his conclusion Dr. Armstrong said, "Not one link in the chain could have been dispensed with." Had he not had the discussion regarding his work and the consequent dispute, the first link in Dr. Armstrong's chain would have been missing. The invention of the superheterodyne might still be waiting for us.

The research worker should be kept well informed regarding company interests and should have an opportunity to share discussions concerning the reasons for the particular problem assigned and the utilization of the results therefrom. If not fully informed, the investigator may let an experimental observation pass by as of no interest. On the other hand, the observation, if properly presented, may change the course of the program.

An effort should be made by the company to avoid, as much as possible, regimentation of the research worker. When the laboratory and the plant are under the same roof, this is not always possible. Restrictions necessary for the plant worker, if applied to the same extent to the research worker, will be reflected both in his type of thinking and in his attitude toward his work.

Most industrial research men will be more productive and efficient if allowed the maximum responsibility and freedom in the prosecution of their work and if at least a small percentage of their time is available for work of their own choosing, which may or may not have immediate application or economic interest. The opposite extreme will reduce the trained professional to the level of a scientific technician.

It requires co-operation and effort on the part of both the company and the individual to bring about the full professional growth of the research man. Unless he does reach his full stature the company will not profit as greatly as possible from its man, nor will the man contribute as much as he might. There are many factors which will bring about full growth and each has its own place and importance. The facilities available to the individual are many and diverse. He should not neglect his professional societies, his periodicals, the research centers, or the opportunities for discussion. The company must itself be aware of these things and allow the opportunity for full growth.

Modern industry without the research man would drift backward many years, and the research man without the co-operation of modern industry would be relegated to the lonely, tortuous paths of the past.

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CHAPTER XVI

The Location, Design, and Construction of a Modern Research Laboratory

Location

The problem of choosing a site for an industrial research laboratory is one that has given rise to considerable difference of opinion among research directors and industrial executives. The principa question at issue is whether the research laboratory should be situated right at the manufacturing plant, where the research personne can be constantly in contact with production problems, or at a location more or less remote from the plant, where the intrusion of production problems is deliberately avoided. Recent tendency ha been for large industrial concerns to move their research laboratorie away from the factories, but many have resolutely clung to the olde notion of close proximity, and there has been one notable instanc in which the research work has been removed from the factory environment and subsequently brought back again.

But there are other questions also, and the whole problem i complicated by a number of intertwining and somewhat conflictin factors. The most important of these factors, as revealed in twenty four replies to a questionnaire which was sent to research director and other executives of representative industries in the United State (aluminum, automobile, chemical, explosive, gas, glass, machinery nickel, oil, rubber, soap, telephone, and others), are the relation o the research division to other departments within the organization the relation of industrial research to universities and other cultura institutions, the size and type of the business, and the various miscel

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This chapter by Howard E. Fritz, Vice President, Research, and Douglas M. Beac the B. F. Goodrich Co.

laneous considerations of an economic, physical, and psychological character.

Relation of Research to Other Departments Within the Organization

The prime factor in choosing a site for an industrial research laboratory is the place of the research division on the organizational chart. This varies from one company to another on account of different conceptions of what constitutes research and of what the proper relations should be between research and the other company activities, particularly production. Historically, industrial research was originally closely linked to factory development and control, and there was little attempt at a close demarcation of these different functions. They were all carried on in a laboratory situated either in a factory building or close to the factory. Even now, there are many who maintain that no sharp distinction can be made between research and development. This is often reflected on the organization chart by the words "Department of Development and Research," and in many cases the main activities of a department labeled as a research department are actually factory development and control rather than research in the narrower sense of the term. For industrial concerns in which research is thus integrally joined to factory development and control there should ordinarily be no thought of locating the laboratory away from the factory.

But the question whether or not factory development or any part of it should be designated by the name of research has now become a moot question of much more than academic interest. A very strong school of thought maintains that research and development are entirely separate functions, with different purposes and methods, and requiring a different kind of training on the part of the staff, as well as a different attitude of mind. To this school, the concept of research in industry is confined to systematic study and experimentation whose principal aim is the invention of new products and new processes of commercial value.

Factory development and control, on the other hand, are concerned with (1) the design, development, and testing, for factory production, of the new products and processes resulting from research, and (2) the improvement of products and processes already in use. In accordance with these conceptions, the research worker must be an unbounded optimist, looking always to the future, even to the distant future, and he must be given complete freedom from the demands of the present to pursue his quest of the unknown and his discovery of the new. It is natural that those who consider freedom to be the essence of research should press for freedom of the research department from the production department, in fact as well as on paper. In numerous instances, this independence has been achieved only by the complete removal of the research laboratory from the factory premises.

Nevertheless, even in industrial concerns in which the organizational independence of research has been established, there appears to be considerable difference of opinion as to just what the relationship between research and production should be. There are some who hold that even when they are separated on the organization chart, research and production should nevertheless maintain the closest possible personal relationships with each other, and that this can happen only if the two divisions are in close physical proximity. It has been stated that frequent personal contacts between the research staff and the plant operators and technical men are necessary "to keep the research men in touch with reality" and to keep the factory operators and technicians in touch with new scientific discoveries. A few companies go so far as to require their research men to spend some time in the factory to get a general first-hand notion of the manufacturing processes. Other alleged advantages of close proximity between research and production are "the occasional drawing of research men with their scientific attitude into the manufacturing organization" and "the convenience with which the manufacturing people can get assistance and advice from a research laboratory close at hand."

On the other hand, close physical proximity of research to the factory tends to produce an altogether undesirable relationship between research and production. "If the research laboratory is located at the plant, it is extremely difficult to keep it free from pressing factory problems which the plant managers feel can be handled more adequately by the research laboratory than by the plant control laboratory. There is grave danger of the research laboratory becoming a mere adjunct of the plant control laboratory." If the staff of the research laboratory are constantly diverted from their proper functions, to assist in problems pertaining to specification, inspection, testing, or process development, the continuity of their research work will be broken and they will lose that independence of spirit which is the prime requisite of successful research. Furthermore, if the salaries of the research staff are in keeping with their training and responsibilities, it will be a costly business if their time is occupied with routine analysis or short-time development problems instead of research. The constant intrusion of factory problems into the research laboratory and the fear of domination of research by production have provided a strong impulse to the present tendency to move the research laboratory away from the plant.

There are some who advocate a compromise by moving away from the factory only that part of research known as "pure research" or "academic research," the purposes of which are said to be the assembling of data, the discovery of scientific principles, and the establishment of theories, quite regardless of their commercial value. This is the kind of research usually associated with the universities, sometimes called "fundamental research." Nevertheless, fundamental scientific studies occupy a more or less important place in the research programs of most large industrial concerns, since they often result in the discovery of new products and processes of commercial value. The tungsten lamp is an outstanding example of a new commercial product discovered in this way. The point to be noticed is that when an industrial concern undertakes a research program the immediate aim of which is merely to expand the frontiers of science, the ultimate aim, like that of all the rest of industrial research, is to apply the new knowledge to commercial ends.

Some of those who advise moving only fundamental research away from the factory have a different conception of "fundamental" from that just described. They consider problems of factory control and development as one kind of research, and the search for entirely new products and processes another kind of research, which they call "fundamental." In other words, their term "fundamental research" means simply real research, and their advice boils down to moving the research work away from the factory, leaving the other technical activities behind, including engineering development, sales service, and inspection and testing of raw materials and finished goods.

The question of moving the research laboratory away from the factory is further complicated by the relations between research and the administration. Because of the leading part which research has to play in determining future company policies, as well as for other reasons, many maintain that not only should the research division be closely linked to the executive division on the organizational chart, but also the research laboratory should be in close physical proximity to the administrative offices. Some advocate this location because they feel that it is necessary "to sustain the interest and understanding of the top management of the company." Others advocate it because they take an enlightened management for granted—a management which fully recognizes the vital importance of long-range research to the continued prosperity of the company, a management which insists on the closest possible contact between the research laboratory and the top executive staff, together with the patent department, division managers, and central engineering.

For such reasons, some companies whose administrative offices are in a different locality from the manufacturing plants have established their research laboratories near the administrative offices rather than near the plants. This is true, for example, of several of the large oil companies (American, British, and Dutch) which have an added inducement in the fact that their refineries are scattered all over the world, making it difficult to select any particular one of them as the research center. Some companies, however, have taken the opposite view and have considered it more important to locate their laboratories at their manufacturing plants than near their central administrative offices. Such a choice would be natural for laboratories in which research and development were combined.

When the executive offices are located at the manufacturing plant, it is evident that the desirability of moving the fundamental research laboratory away from the factory must be weighed against the desirability of keeping it near the administration. A very interesting case in point is that of General Motors Corporation, whose research laboratories were brought back to Detroit from Dayton, Ohio, not because Dayton was too far from the factories but because it was too far from the central administration. If removal of the research laboratory from the factory also involves its removal from the center of the administration, the exact distance of the removal may be an important consideration. The research director of one of the large oil companies writes as follows: "In separating the research laboratory from the plant, I think it is easily possible to get too far away. One petroleum laboratory I know of is something ike 1,000 miles from their nearest refinery and not too convenient o their main office. We, on the other hand, are about four miles rom our main plant and four miles from our main office." Several ther correspondents prescribed the formula, "Away, but not too far away."

Relation of Research to Universities and Other Cultural Institutions

The modern industrial research laboratory should have fairly close relations with the universities, which are the natural training ground of most of our research men. Actually, the universities are being used by the research divisions of a great many of our large industrial concerns for the following three purposes: (1) recruitment of personnel; (2) "co-operative research," consisting of special studies and research projects conducted by the universities and financed by industrial concerns; (3) attendance by members of the companies' research departments at lectures and courses given by the universities. To enable the staff of an industrial research laboratory to attend evening courses or occasional lectures it may be advantageous to locate the industrial laboratory near one or more universities or technical schools.

PHOTO. 19. First unit of the Murray Hill laboratories of the Bell Telephone Company. (*Courtesy of the B. F. Goodrich Company.*)

The case is well stated in an answer to our questionnaire from the director of a large industrial chemical research laboratory:

> Another factor which was in our minds when we located our research laboratory here was the problem of combating obsolescence of the men themselves. For every million dollars you invest in a chemical plant,

> you are likely to charge off from $100,000 to $200,000 or more to obsolescence. An industrial research problem may be relatively narrow. The man working on it is sometimes less valuable at the end as far as a new problem is concerned than he was before he started it, because he has lost touch more or less with the broader aspects of his field of science. We like to have our men take graduate lectures, listen to visiting speakers, etc., and find the scientific schools here convenient from that angle. We have cooperated with them in setting up lecture courses specifically designed for this purpose.

It may be added that the recruitment of good research men is easier when the candidates for research posts know that their laboratory will be within easy distance of universities, libraries, learned societies, and other cultural institutions.

The cultural factor appears to have been weighted more heavily in recent years than formerly, and a number of new industrial laboratories have been purposely located near universities and technical institutions. There are a few instances in which the cultural factor has been the cause of some agitation for a change of locale for the research laboratories, but has had to succumb before the preponderance of other factors.

Size of Business

The size of a company's business and the amount of its resources constitute a factor which controls the extent to which research can be separated from factory control and development. A small business will usually be able to afford only a single laboratory to carry out all its technical experimental work, most of which will be directly connected with factory production. In somewhat larger concerns, a certain degree of separation is feasible, and two or more separate laboratories may be established, one of which is devoted mainly to research, but is still responsible for a considerable amount of development and control work in order to avoid duplicating apparatus, or for other reasons of economy. It is normally only in the really large concerns that a practically complete functional segregation of research is possible, and it is therefore only these large establishments which have to consider the possible advantages of locating the research laboratory away from the factory.

The various degrees of separation of the research function from factory control and development, as outlined above, represent stages in the historical growth of many of our largest industrial concerns from their small beginnings to their present huge dimensions. But though the separation of research from development, so desirable from every theoretical consideration, is thus possible in large industrial concerns, it has not very often been attained, and at least one important research executive actually adduces the largeness of his company as a reason for keeping research and development together. As this is at exact variance with the views given above, it may help to balance this section by concluding with a paragraph from the letter in which this opposite view is clearly expressed:

> There are three general ways to handle a research laboratory: (1) as an entirely independent department, reporting only to the chief executive of the company; (2) as a special branch of the production or manufacturing responsibilities, reporting to the executive in charge of manufacturing; (3) as a branch of the staff technical organization. *This last plan seems to suit large integrated companies* * such as our own which are required to maintain not only research and development staffs, but also important general engineering staffs, process and product control staffs, and patent departments. Where the technical organization gets to be this large and complex, it seems to work out best to group all of these closely related technical functions into a single integrated technical staff organization. Where this situation exists it is obvious that part of the technical staff has to have continuous contact with the manufacturing staff on new construction and other major engineering problems, on testing and maintenance of quality, on efficiency or performance testing of plant operations from a technical standpoint, and on development work which includes pilot plant operation. Where the organization is set up in this way it is very much more difficult to put the research laboratory at a remote location.

Type of Business

The problem of finding the best location for an industrial research laboratory may assume quite different aspects according to the nature of the business or according to the products manufactured. One of the research directors in the steel industry expresses this idea in the following terms:

> It is very difficult to lay down principles in line with my experience which would meet all questions which might develop in companies with different research and product interests. It is clear that the percentage of facilities in a centralized laboratory devoted to purely fundamental work in one industry may be quite different from that in another. For example, I am sure that the proportion of effort pointed to advanced fundamental developments in the chemical industry should be much greater than in the steel industry.

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* Authors' italics.

While not all of us would agree with this opinion, it shows that there are some who think that fundamental research is less important in the steel industry than in some other industries, and that therefore there would be less reason for locating a steel research laboratory away from the plant.

On the other hand, there are types of business which have special inducements to locate their research laboratories away from the factory and if possible away from the city. Telephone companies, for instance, should find a quiet country site far more favorable for their experimental research in the field of acoustics. The Bell Telephone Laboratories, located in the open country at Murray Hill, N. J., find that one of the great advantages of a country location as compared with the city or industrial site is that by proper choice, such a country site is freer from all sorts of man-made disturbances, including electric and acoustic interference, low-frequency vibrations, dust, and dirt.

Again, companies with several manufacturing plants have a different problem from those having a single plant. When there are several factories, the question arises as to which of them, if any, to select as the locale of the research laboratory. Four different methods of research organization are possible, and all of them are actually to be found in industry. First, the research laboratory may be established away from any of the plants and preferably near the central offices. Second, the research may be organized at one of the manufacturing plants, selected in preference to the others, sometimes because it is the largest plant, sometimes because it manufactures a greater diversity of products than the other plants, and sometimes simply because it is the oldest plant, and the research work has been established there before the other plants have been built. Third, laboratories may be established at each of several plants. Fourth, laboratories in which research is closely allied to factory development may be organized at several plants, with an additional central laboratory away from the plants and devoted chiefly or entirely to fundamental research.

Numerous examples could be given of the successful operation of all four of these methods of organization in present-day industry, and the arguments of the proponents of each method would make a chapter by themselves. Suffice it to say that the consensus appears to favor centralization of fundamental research, preferably at a location some distance away from any of the manufacturing plants, but decentralization of research or quasi-research which is more or less directly connected with factory operations.

From what has been said, it is evident that the problem of locating the research laboratory is affected in different ways according to the nature of the business, and it is questionable whether it can be solved for all companies by any such simple formula as that suggested by the late Thomas Midgley: [12] "Possibly the solution for maximum results can be obtained by having two research laboratories, one at the plant and another a few hundred miles distant. Ultimately, the problems each is best adapted to solve will find their proper atmosphere."

PHOTO. 20. The modern air-conditioned research laboratory of the Firestone Tire and Rubber Company. (*Courtesy of the B. F. Goodrich Company.*)

Economic Considerations

Various considerations of economy will overlap the other factors in selecting the site for an industrial research laboratory. Small companies possessing only a "one-man laboratory," or a small laboratory in which research and factory control are combined, will usually find it most economical to set up the laboratory in one of the factory buildings. Large companies may sometimes keep their research laboratories at the plant for economy of service facilities and in order to avoid duplication of instruments and other equipment. It goes without saying that in choosing between several available sites for the research laboratory, relative costs of installing and maintaining such essential services as water, gas, and electricity must be carefully weighed. And finally, the factor of the availability and cost of land may point toward a location at some distance from the plant. In this connection, the following statement from the director of research of a large company is pertinent:

> Another good reason for locating the research laboratory at a little distance from the plant is that the plant site naturally being located with regard to railroad facilities and other considerations which are important for the transportation of goods, etc., is usually quite limited in extent, in a plant which has grown as most successful plants have done, and the acquisition of additional space is either impossible or quite expensive. One of the desirable features of a separate site is that it can be located at a point which is not accessible by railroad spur, etc., and hence it is feasible to acquire a considerable acreage without running into prohibitive costs. We believe it is desirable to have extra space, so that temporary buildings, pilot plants, and other desired facilities may be installed later, and torn down or built up as desired without having to be unduly crowded by the demands of manufacturing operations for the use of expensive acreage.

Physical Considerations

The importance to telephone research laboratories of freedom from electric disturbances has already been mentioned. There are several other kinds of physical interferences with the taking of accurate measurements and "the leisurely and concentrated study of problems." Among these are noise, vibration, smoke and soot, odors, temperature, and humidity. Vibration of buildings, for example, causes sensitive instruments to get out of adjustment frequently and may preclude the use of such instruments as infra-red spectrometers and electron microscopes. Air-borne soot and smoke from the factory may interfere with many research techniques requiring a high purity of materials and cleanliness of apparatus. The desire to escape from such paralyzing physical influences has impelled many industrial concerns to move their research laboratories to the country, away from the smoke of their own factories, and away from the noise and vibration of the city.

Psychological Considerations

Quite a number of our correspondents have emphasized the beneficial effects on the morale of research men produced by locating the laboratory away from the factory environment. One of them wrote as follows: "I think one should remember, too, that research work is a psychological matter. Many research men are impelled by pride to a considerable degree. From this angle it is good to have them off by themselves, where research is the business of the day, in a place where nothing is more important than research." Aside from giving research men a greater pride in their work, isolation from the factory promotes a feeling of freedom from intrusion or interference with their work, freedom to think things out, and work things out without hurry and without fear of interruption. Two other advantages of the non-factory site which have been mentioned in connection with morale are (1) freedom from various unsettling factory personnel problems and (2) the fact that it is possible for the research staff to house themselves comfortably and satisfactorily near their work.

This is hardly the place for a detailed treatment of the psychological factor in research, and the brief statement given above is merely intended to show that research leaders are well aware that the physical location of the laboratory has a very direct bearing on the important problem of creating a favorable psychological environment for research.

Summary

The nearest approach that can be made to a definite prescription of how to select the best location for an industrial research laboratory is a list of questions that must be squarely faced by each company in making its selection of possible sites. These questions are:

1. Will the best relations between research and other departments, especially the production and administrative departments, be fostered by locating the research laboratory at the factory or at some distance away?
2. What cultural opportunities are offered in the neighborhood of the proposed laboratory site?
3. Is the company large enough to afford a separation of research from factory development and control, and if so, is such a separation desirable?
4. Are the company's manufacturing plants near one another or scattered? If the latter, should the research work be located at one of the plants, or at several, or away from them all?
5. What are the comparative costs, at different locations, of building, equipping, and maintaining a research laboratory?
6. Is the proposed laboratory site free from physical hindrances to accurate research work, particularly noise, dirt, and vibrations?

7. Does the proposed site provide a favorable psychological environment for research, giving the research worker a feeling of freedom, comfort, and pride in his work?

The answers to these questions may conflict with one another and will vary from one company to another. The examples that have been given of the variable amount of emphasis which has been placed by different companies on each of the many intertwining factors involved should show that it would be difficult for anyone not intimately connected with a given industrial concern to prescribe an ideal location for its laboratory. "Every industry has its own problems and every company in a single industry is undoubtedly different from every other company. The personality of the company, if you wish to use that term, very probably defines the requirements more than anything else." It is the intangible elements constituting the personality of a company which determine the relative weight that should be given to each of the seven factors submitted above.

Functional Design

The functional design of a modern industrial research laboratory must have as its primary object the provision of a work space for the individual research worker entirely adequate and convenient for his needs. It is also desirable to provide for some flexibility in work space, to allow for future needs, in so far as they can be foreseen or imagined. Further considerations of importance are the establishment of convenient routes of circulation, the provision of well-designed general facilities, such as library, shop, stores, and clerical service, and the integration of all of these portions into an economical structure of good appearance. In general, the laboratory should be neither shop nor monument; rather, it should be a clean, conveniently arranged working place where delicate operations can be carried on.

The Module

Functional planning in accordance with these criteria is greatly assisted by application of the module idea, one of the main motivating forces of modern architecture. A module is a repetitive space pattern. And it is a fact that, though modern laboratory research is so diverse in its techniques and operations, it is surprisingly uniform in its pattern of space occupancy. The work is done largely at typical laboratory work tables,* of which the general dimensions and arrangement are well standardized. Departures from the norm in this regard have been generally unsuccessful in economy, convenience, and appearance. Acceptance of this standard permits establishment of the module as the space required for one research

Photo. 21. Changing a partition in the Murray Hill laboratories. This flexibility of space is one of the outstanding features of the building. (*Courtesy of the B. F. Goodrich Company.*)

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* However, see footnote, page 329.

worker; this space can then be worked out with painstaking attention to detail; when the design is complete, it is multiplied as required to make the laboratory. The module is capable of integration into any type of structure, from small detached one-story buildings to large multi-story edifices, with equal success. The application of the module system to laboratory design is quite recent; an early example of a large project handled in this way is the Bell Telephone Laboratories,[8, 11, 18, 24] at Murray Hill, N. J., construction of which was commenced in 1940. It must be emphasized that the module idea does not imply a partition at each line of separation of modules; a room may be made up of one or many modules.

PHOTO. 22. A four-man chemical laboratory of the Firestone Research Laboratory. *(Courtesy of the B. F. Goodrich Company.)*

Laboratory planning may be done in two other ways, both of which are open to certain criticisms. One of these is to plan most of the laboratory space as a series of identical rooms or suites, or possibly with rooms of two standard sizes;[5, 7, 23] the remainder of the space is then left as one large room, in which extraordinary operations may be performed. Often the result of this method of planning is that all the laboratory work except the most routine analyses and preparations is done in the "back room," since research operations have a way of being extraordinary. Another way is to plan each room carefully to house the work to be done in it, and expertly dovetail these various rooms into a building. This method of planning fails because prediction, particularly in research, is a lost art. The usual result is that the greater part of the work of the laboratory is done in poorly adapted space, and subdivisions are wholly without logic. The discussion which follows is, therefore, based on the module idea.

There is surprising unanimity among existing industrial research laboratories as to the minimum essentials required in the space for the individual research worker. These may be tabulated as follows:

Work table space—16 to 24 lineal feet, 2 to 3 feet wide.
Working aisle—3½ to 4½ feet wide.
Services to the work table, in order of importance:
  Drains.
  Water (cold).
  Electric power (110-volt alternating current).
  Fuel gas.
Services to the work unit:
  Artificial lighting, about 25 foot-candles intensity.
  Ventilation, providing both supply and exhaust of air.
  Heating.
Desk space for keeping the records and reporting the results of research.

There is less agreement as to the amount of storage space required in the individual unit, some laboratories providing very little, and others as much as 180 cubic feet. It may be remarked that many laboratories give a cluttered appearance to a visitor because an obvious shortage of storage space requires use of the floor or work table for storage, usually temporary, of samples, equipment, or supplies. About 80 cubic feet (gross—inclusive of construction, bases, and the like) of drawers and cabinets are usually provided for storage space in the working module; this is often supplemented by home-made shelving within the module, as well as by "dead-storage" areas elsewhere in the building.

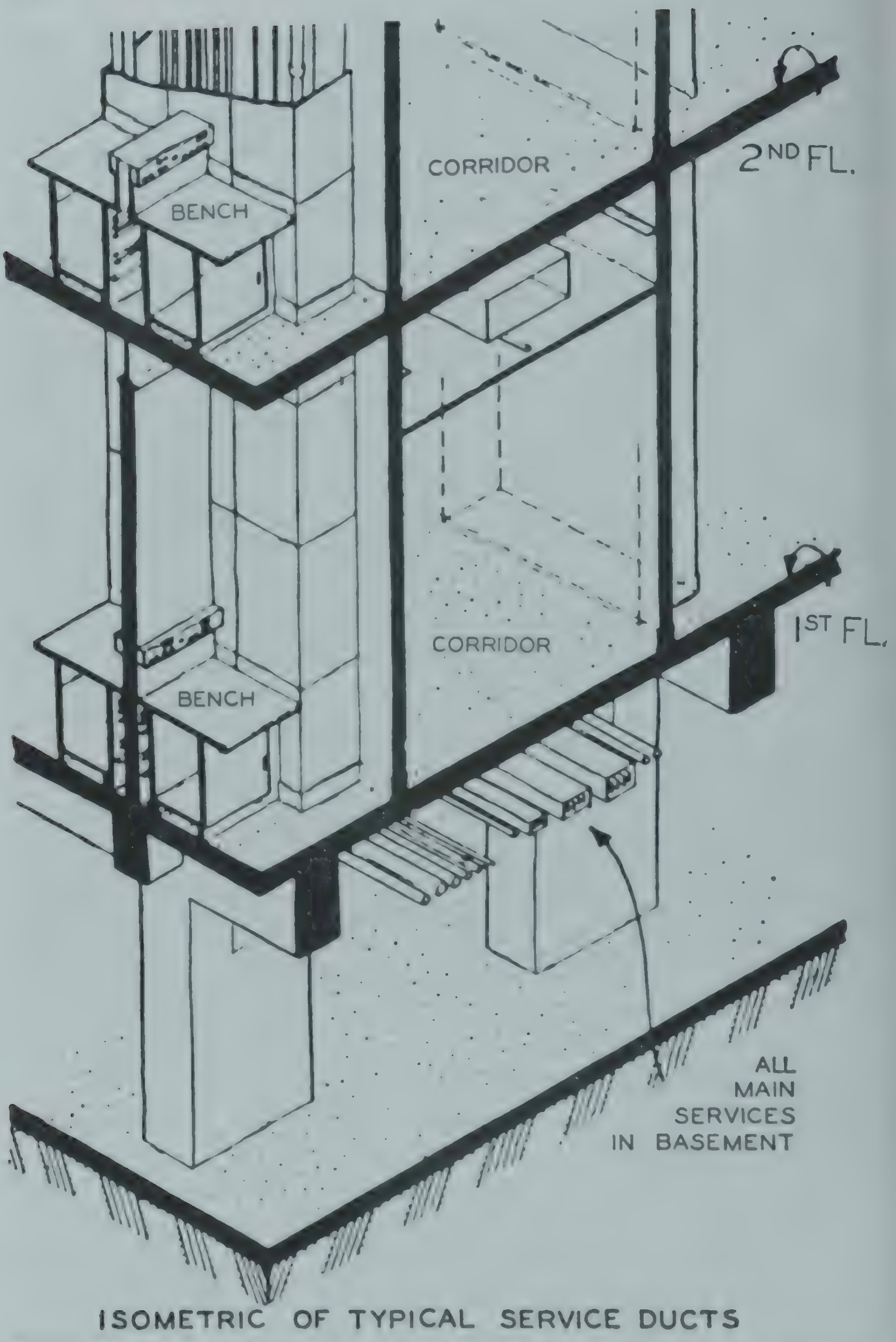
CORRIDOR
2ND FL.
BENCH
CORRIDOR
1ST FL.
BENCH
ALL MAIN SERVICES IN BASEMENT
ISOMETRIC OF TYPICAL SERVICE DUCTS

PHOTO 23. Diagram of the horizontal and vertical distribution of electric power, water and other services at the RCA Laboratories. (*Courtesy of the Radio Corporation of America.*)

Central Services

There is also some disagreement concerning provision of further central services to the work unit or the work table. Some modern laboratories [18] supply, in addition to the services above, some or all of the following:

Hot water.
Compressed air.
Steam.
Electric power of various characteristics.
Distilled water.
Vacuum.
Gases other than fuel gas and air, such as O_2, N_2, CO_2, H_2S, NH_3, and the like.

Provision of these services from central sources is sometimes not regarded as essential, since each can be supplied within the work unit as needed. The merits of central supply of each of these services must be examined by every organization, and decision made in accordance with its peculiar requirements. Perhaps the most important factor in deciding whether to centralize or decentralize a given service is the quality of the supplies. For example, many research workers have stated that central distilled water and vacuum supplies are of too low and variable quality for modern research work. On the other hand, compressed air of adequate pressure for all ordinary laboratory work may be readily supplied from a central source; small individual pumps for this service ordinarily produce a much poorer quality supply. The provision of central supply of many gases is open to question on the ground of inadequacy, since central supply of all known gases is obviously impossible, and the research worker will infallibly select the one not centrally available as the *sine qua non* of his next experiment. Gas cylinders are cumbersome impedimenta in a modern research laboratory, but it seems at present that they will be with us for some time.

The services are brought to the laboratory module by a piping and duct system which is either essentially vertical,[7] the mains passing through shafts placed as needed in the building, or by one which is essentially horizontal,[17, 21] the mains passing under the floors and risers going to the equipment. Both methods are satisfactory from the standpoints of operability, accessibility with concealment, and cost. It is believed that the horizontal system of distribution has some advantage of flexibility in that it permits throwing many modules together into larger rooms, free from interference by the vertical pipe shafts. A single vertical shaft placed at the core of the building connects the horizontal mains to the supplies. In both methods, the piping of the lowest floor is sufficiently complicated to make the provision of a pipe cellar almost mandatory. Ventilating and electrical equipment may also be housed in a basement.

PHOTO. 24. Basement distribution of electric power, water, gases, etc., at the RCA Laboratories. (*Courtesy of the Radio Corporation of America.*)

Professional Planning

Obviously, planning a research laboratory is a sufficiently complicated business to warrant engaging the services of a capable professional architect at an early stage. Full co-operation between the architect and a committee of company engineers, who are able to furnish not only information as needed but also constructive criticism of the architect's plans as they are evolved, should minimize the possibility of serious blunders.

Integration of the essential work table, desk, working aisle, and services into a module having the requisite characteristics of adequacy and amenability to change is a feat of design requiring painstaking care. Any error or extravagance committed here will be multiplied many times. A few suggestions for this step may be advanced. It is certain, however, that no one attacking this problem will regard any solution adopted by previous builders as finally and completely acceptable.

Arrangement

In commencing the design of the module, it is helpful to know the range of dimensions, the orientation in the building, and the placement of major pieces of equipment previously used by others, as a starting point from which to work. In actual practice, as seen in visits to twenty-four modern laboratories,* the long, narrow space required for a work table and its working aisle, the writing desk, and any storage space allotted, has ranged in dimensions from 6 feet by 24 feet to 11 feet by 32 feet. The module is disposed with its long axis perpendicular to the window wall since orientation parallel to the window wall would result in an excessively narrow building, large proportion of corridor to operating area, research workers continually facing the window or working in their own shadows, and excessively long runs of service piping. It seems natural to place the writing desk near the windows, and high equipment with superstructures, such as fume hoods, away from the windows, at the corridor.

For reasons of safety which seem self-evident, a means of exit should be provided near each end of a module. The secondary exit has been provided in a variety of ways: as a continuous balcony on the outside of the laboratory building,[28] as escape trapdoors built over the laboratory benches,[13] and as secondary aisles next to the exterior walls of the building.[7] The last of these is probably the most desirable, but also the most expensive, since a larger module is required when the secondary aisle occupies some of the area. Escape trapdoors in partitions over work benches seem to be open to serious question, since they may very possibly be blocked from both sides by the work being done on the bench. The continuous balcony is effective, moderate in cost, but poor in external appearance unless given exceptional architectural treatment. It also excludes some window light in a building of ordinary proportions.

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* References 1, 2, 4, 6, 7, 8, 9, 10, 11, 13, 14, 15, 17, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29.

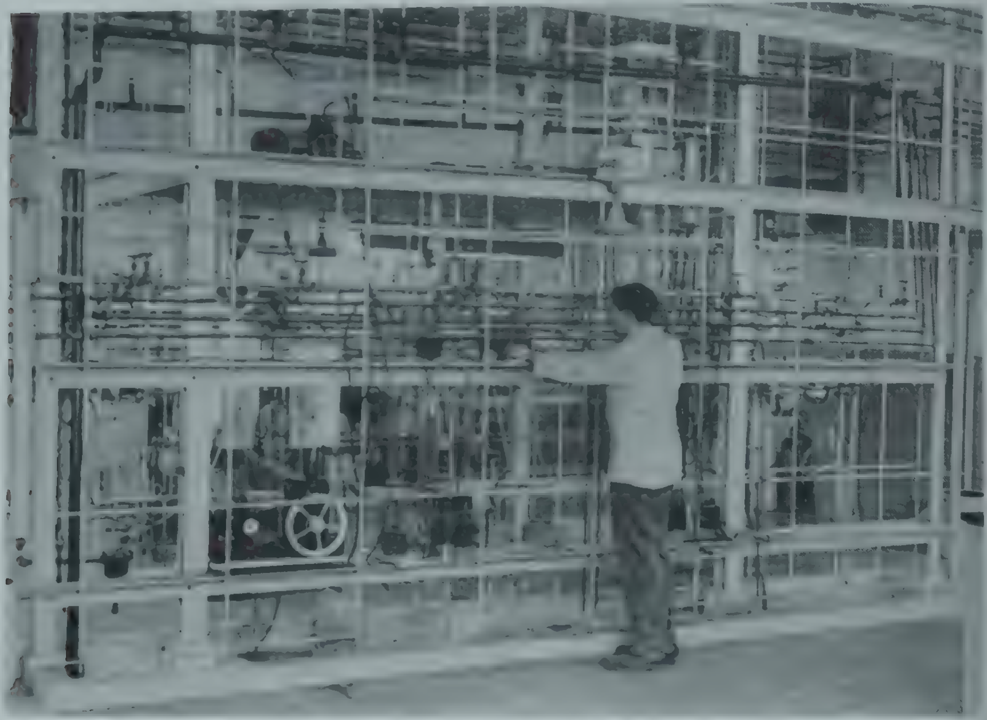

PHOTO. 25. Central support grids permit flexible laboratory set-ups. (*Courtesy of Wyandotte Chemicals Corporation.*)

If, in elaborating the module, demountable partitioning and movable laboratory furniture are used, great flexibility can be achieved for adaptation to future requirements. The concept of the room, with its immovable enclosing walls, is abandoned for the modern idea of open space to be subdivided and equipped as desired. Practical application of the principle of movability of laboratory furniture was initiated by the United States Department of Agriculture, and has been continued by the Mellon Institute for Industrial Research,[5] and many industrial laboratories. This principle can even be applied to the long laboratory work tables by replacing the present commonly accepted immovable table tops with removable covers, which may be constructed in sections if desired, and which may also possess superior qualities of resilience and chemical resistance, as well as pleasnt color, warmth to the touch, lightness, strength, and liquid-tight, emporary jointability.

Having elaborated a module which is standard, yet prepared for hange, the laboratory planner turns to the considerable portion of nodern research which is done with special tools and equipment. At first glance, it appears that rooms might still be required to house activities. If due consideration, however, be given to placing specific equipment items in modular space, along the modular center ines, it will often be found that more economical, elegant, and pleasing layouts are possible than in rooms. Examples of activities which have been housed in modular space are:

Organic chemical research.[13, 17]
Clerical and administrative office work.[13, 17]
Experimental rubber compounding and milling.[13]
Electrical and electronic research, including radio research requiring electrically shielded space.[13]
Physical testing, up to about 1,000,000-lb. loads.[13]
Laboratory shop work.[13]
Stock dispensing.[13, 17]
Photographic processing.[13]
X-ray work requiring lead-shielded enclosures.[13]
Research analyses and control tests.[13, 17]
Textile research.[13]
Foods research.[17]

Only when equipment of very large size, such as pilot plant or factory-scale processing or testing equipment, is to be housed,* it is necessary to plan the spaces to fit individual pieces of equipment. Thus, flexibility is inherent in modular space; it may be used for "ordinary" work today, and transformed to extraordinary use tomorrow.

Windowless Laboratories

In the further development of the module, certain highly controversial matters crop up. An example is the windowless laboratory. Many research workers have disclosed a predilection for natural light in the laboratory, and for windows which can be opened. One reason for this predilection is the conviction that, with all the perfection of modern lighting and air conditioning, insurance against their complete breakdown is required. The failure of the lighting system in a windowless laboratory may result in serious accidents or fires, as workers leave hastily without taking adequate precautions in shutting down experimental work under way. Failure of a hood exhaust system could also cause serious distress, or worse, if a window were not available for the worker to get a breath of air. Nevertheless, an excellent case can be made out for the windowless laboratory, and a few have recently been built, with undoubted success. Some of the advantages presented by a windowless laboratory are: constant experimental environment of designed lighting and air conditioning, unaffected by the vagaries of nature; reduction of costs of heating in winter and cooling in summer; barring of distracting influences from the workers; ready conversion of any room to a dark-room if required for the work being done; and reduction in initial cost of the building. Some of the disadvantages mentioned above may be ameliorated, for example, by providing an emergency lighting system automatically connected on failure of the main electrical supply, and by providing stand-by ventilating units to take up the task when the main units break down.

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* This obviously includes such research tools as wind tunnels, engine test stands, model basins, plutonium piles, etc., which cannot be reduced to laboratory-bench, or even ordinary room, dimensions.

Interior and Finish

A second controversial matter is interior finish and appearance of the laboratory in general, and concealment of supply piping and duct work in particular. Quite apart from the research workers' preconceived opinion regarding the importance or non-importance of the appearance of their laboratory, it is a fact that a new laboratory having a good appearance has been used by many companies for display advertising, and with excellent results. Appearance does make a difference to the public, and the progressiveness of the company to which the laboratory is attached is judged accordingly. Furthermore, after becoming accustomed to a laboratory designed with display in mind, most research workers will confess a preference for such surroundings over the traditional dingy, smoky cell of the alchemist. For these reasons of public and worker acceptance, flush surfaces, light, pleasant color schemes, concealed piping and ductwork, and open arrangement are found in many modern industrial research laboratories. Exposed piping has been insisted upon in the past for ease of maintenance: modern finishing materials, in the form of unit panels which readily snap into (and out of) their supporting framework, are now available which allow easy access for maintenance and yet provide effective concealment with flush, clean surfaces for appearance.[13]

Desk Space

Another controversial point is the policy to be followed in providing writing-desk space for the research worker. The three ways most used are: placing desks in the laboratory area, provision of private or semi-private offices,[7] and provision of large offices, sometimes far from the laboratory area. The last of these methods is extremely objectionable to almost all research workers, since concentration on highly abstract ideas in a "bull-pen" office, with the usual hubbub going on, is next to impossible for most people. Most research workers favor separate offices, for various reasons, but the advantage of assuring the physical presence of the worker in his laboratory is often the factor which causes managements to decide to place the worker's desk within the laboratory area, and to subdivide the laboratory as required to permit concentration by the workers.

Ventilation and Lighting

Further matters of a controversial nature are ventilation [18] and lighting. Provision of exhaust ventilation from fume hoods is a generally accepted practice for chemical laboratories. Yet, surprisingly often, its obvious concomitant, forced supply ventilation, is neglected, with one of two disappointing results: either hood draft is made up by leakage, with all that this implies of cold drafts, wind-tunnel corridors, and infiltration of dirt; or, if the building is sufficiently tight, hood draft is reduced seriously below the designed amount, doors are opened or closed with difficulty, and gales of surprising force pour in through any open door or window. Much of the work of the modern laboratory is improved by temperature and humidity control provided by typical "comfort" air-conditioning. Of course, some laboratory work must be done in accurately controlled conditioned rooms. Textile and plastics testing are examples of this. A further argument favoring air-conditioning is the increase in productivity due to workers' comfort; this has been substantiated in many laboratories. It is admittedly expensive to air-condition a laboratory, since general recirculation of air cannot be tolerated, and fume hoods waste great quantities of conditioned air.

Expedients have been introduced to reduce the wastage from the hoods; the usual result is simply to impair the hood draft to such an extent as to make it practically useless. It will be interesting to see what the future will bring in ingenious methods for obviating the loss of conditioned air through fume hoods, without reducing their efficiency.

Of equal importance is adequate artificial lighting. Modern lighting, particularly fluorescent, can be used lavishly at moderate cost and without undue heating effect. When fluorescent lighting is used in combination with a false ceiling of panel construction, luminaires may be massed when delicate work requiring much light is being done or may be widely spaced in areas where little light is needed; changes in the light intensity desired at any point are readily made, as installations are available which appear to be permanent, but actually are readily changeable. This avoids the nuisance of portable lamps and extension cords. Many modern laboratories provide general artificial lighting at an intensity of 25 foot-candles, which is believed to be a workable basic standard.

The suggestions presented in the foregoing paragraphs do not by any means complete the design of the module. Further points, which must be left to the discretion of the designer, are: decision as to floor-to-ceiling height, provision of main circulation routes and secondary circulation routes (desirable from the standpoint of safety); disposition of supply mains and branches to each module; selection of amount, kind, and disposition of storage space in the module; and selection of color scheme and finishes.

Integration of Units

With the design of the module complete, there remains the problem of integrating the required number of modules into a building or buildings at once economical, efficient, and pleasing in appearance. Great reliance must be placed on the architect in this phase of the work, but constructive co-operation and criticism by the building committee are also imperative.

The first decisions to be made are the number of buildings and the number of stories required. The character of the work being done often dictates the separation of certain functions from the main laboratory building. For example, any work of large scale may be most effectively housed in a structure planned for it and separated from work of a more delicate nature. The number of stories will sometimes be based on the total amount of space required, or on the land area available. In a preponderant number of intermediate cases, however, these are not controlling factors; and, in these cases, buildings of two or three stories plus basement have almost invariably been chosen. When higher buildings have been planned, it has been necessary to include passenger elevators for conservation of time of personnel. Single-story structures give poor economy of roof and wall, and have greater heat losses in winter and gains in summer. The building, if of average size, will then be organized in wings abutting a central core. At this point, care must be exercised that any essential service functions placed in the central core be amply designed—even over-designed—since additions to the core are made only with difficulty. The extended ends of the wings may be designed to be added to with relative ease. Provision for expansion may also be made, on a large site, by installing service lines in pipe tunnels along main driveways,[10] so that future buildings may be economically connected to the required services. This method gives certain large-scale flexibility comparable to the small-scale flexibility afforded by sectional laboratory furniture and demountable partitions. Entire new lines of research may be accommodated in new buildings of standard design, and special functions unforeseen when the first structures were erected may be readily taken care of in structures designed for the purpose.

Organization of the building requires the placement of a good many service functions in satisfactory relation to the laboratories. The service functions used often by the research workers should be centrally located. Among these are the library, stockroom, shop, and glass blower; those to which research workers need seldom go may be located as desired. It is well to arrange the initial organization of the building so that laboratories with the most fume hoods are located on the top floor, so that their exhaust ducts may have short runs; for flexibility, however, provision should be made so that fume hoods may be added at any location without major mechanical work.

When a building is functionally organized as described, it will present a severely practical outside appearance. Here again the architect is required, to ameliorate the severity and make an inviting building.

Most managements will, quite properly, demand close attention to economy in the design of a new research laboratory. It should be noted, however, that the largest item in any industrial research budget is salaries; therefore, any design feature which can be shown to contribute to the productivity of the staff will prove to be true economy.

PHOTO. 26. Some research laboratories have bay arrangements designed to encourage free exchange of ideas and discussion of problems among groups. (*Courtesy of the American Cyanamid Company.*)

Remodeling Existing Laboratories[19, 24]

Businesses with established research organizations face the necessity of modernizing their laboratories about every twenty years Three courses are usually open for such a program: remodeling the existing laboratories, building new laboratories, or remodeling for laboratory use some other existing structure. In choosing among these courses, several factors must be weighed: location, adequacy of existing structure, and total cost.

In beginning an investigation with a view to remodeling an existing laboratory, the present site should be critically examined, just as if it were a new one. Is it favorably located with respect to proximity to management, production, and markets? Does it have the essential physical conditions of cleanliness and quiet, light and air and an adequate supply of essential services? If the present site is deficient in any of these important respects, full value cannot be obtained from an expenditure for remodeling.

Further, the adequacy of the existing structure, regarded simply as a shell, should be considered. Is the floor area of the building adequate, after reorganization, to care for present needs, or will extensive additions be required? Application of the rule of 400 to 500 square feet of gross area per person on the contemplated staff will give a preliminary answer to this question. Will the present structure withstand the loads imposed by the proposed laboratory operations, or will reinforcement of the building frame be necessary? Are the existing walls load-bearing with small glass area, or are the windows capable of enlargement as desired? Is the wall-to-wall depth of the building adequate for laboratory furniture? Is the floor-to-floor height great enough to permit installation of modern systems of piping, electric wireways, ventilation ducts, and artificial illumination? Are fixed features like main entrances, stairs, elevators, and chimneys so located that a useful organization of the building may be set up? If the existing structure is seriously deficient in these important requirements, the economy of a remodeling program may be seriously doubted.

PHOTO. 27. The former E. T. Stotesbury home, Chestnut Hill, Pa., which was converted by alterations to the interior of the building to the Whitemarsh Research Laboratories of the Pennsylvania Salt Manufacturing Company. No alterations were made in the exterior of the building, and the grounds are being maintained as shown in the photograph. (*Courtesy of the B. F. Goodrich Company.*)

Economic Factors

If the site and structure pass these tests, there remains only th
economic factor to be considered. A preliminary estimate of th
saving to be made by remodeling may be arrived at as follows: Th
building shell has a value in today's market (1947) of some $4.6
per square foot of floor area. Dismantling and repair costs will re
duce this by about $1.10 per square foot, making a net saving possibl

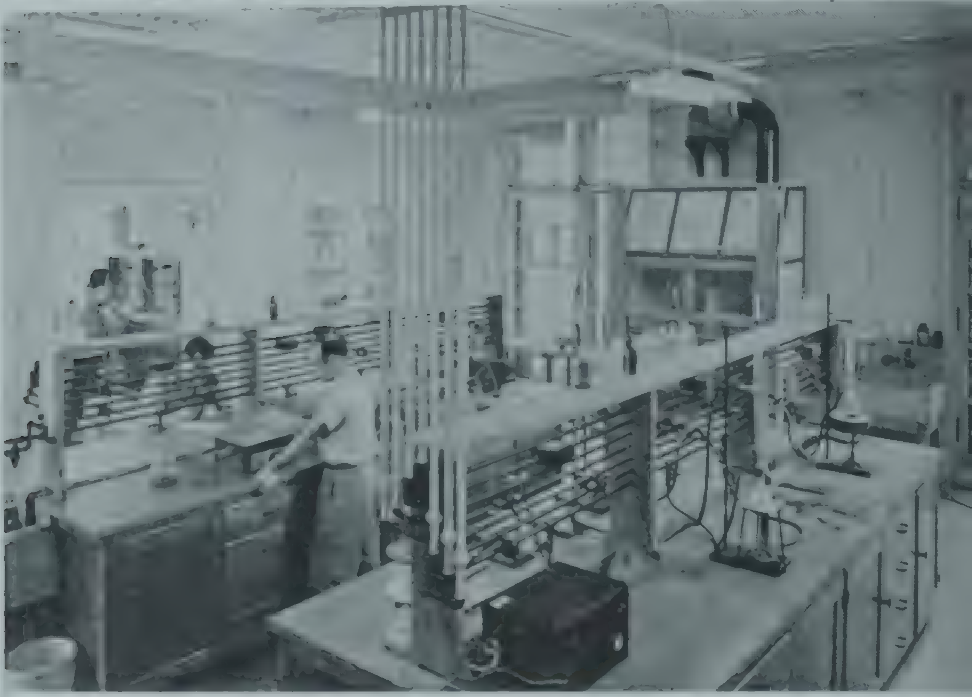

PHOTO. 28. Organic chemistry laboratory in the Whitemarsh Research Laborator
which was converted from a bedroom. (*Courtesy of the B. F. Goodrich Company*

of about $3.50 per square foot of usable space. It may be remarke
here that economic considerations often preclude remodeling
buildings such as mansions, warehouses, and factory or office buil
ings, for laboratory use, since much of the space available cannot b
made useful. Nevertheless, quite a few mansions have recently bee
put to use as laboratories; one example, cited as successful, is th
Whitemarsh Laboratories of the Pennsylvania Salt Company.[16] O
the other hand, there is the case of another large residence which w
carefully surveyed as a possible research laboratory by two corpora
tions, and which could not be used for economic reasons. In th
case of a loft-type structure, where areas are not divided by bearin
walls, efficient remodeling for laboratory use may be easily possibl

Extent of Remodeling Required

If the preliminary economic test mentioned above indicates an interesting saving, a final test may be made by preparing preliminary plans both for remodeling and for an adequate new building, and omparing the estimated full costs of each. In planning the remodeling job, it must be recognized that to obtain full value, the remodeling must be ruthlessly complete. All vestiges of bygone eras must be swept away, to make room for tomorrow. All interior partitions which do not fit into the new scheme in location or finish should be eliminated, together with old floor coverings, wall finishes, and the like. Most, if not all, service and drain piping, electric wiring and controls should be removed. Ventilation and lighting systems will usually be entirely inadequate and should be scrapped. Of course, the old laboratory furniture will usually lead the procession to the scrap pile. Now, with the basic structure of the building exposed, it should be carefully examined; foundations, walls, floors, windows, and doors should be repaired, rebuilt, or replaced as found necessary. When the building shell has been made as nearly equal as possible to that of a new building, effective remodeling will not prove difficult. Piping and electric wireways are most easily installed in horizontal, rather than vertical, distribution systems, when walls and floors exist, since these are usually painfully lacking in pipe shafts and chases. These systems and ventilating ducts are easily concealed, for the sake of clean appearance, between the floor slab and one of the modern unit-type removable hung ceilings. The artificial lighting may be incorporated as flush panels in such a ceiling for modern effect. Movable partitions of steel or cement-asbestos board, with wall finish of the same material, are just as effective in remodeling as in new construction. The module system of organization of the space may also be used; it must be remembered, however, that the size of the module will be dictated by the placement of windows and columns in the structure, instead of by the equipment to be housed, and thus may be less flexible in purpose and operating convenience.

Such a remodeling job, as is readily apparent, is not a superficial affair of paint, glass, floor coverings, and a redecorated lobby. Its planning requires care equal to that for an entirely new building. When handled in this way, remodeling may produce results about the same as those which may be expected in a new laboratory, and

several actual cases could be cited of satisfactory complete remod
ing of outmoded or outgrown industrial research laboratories.

On the other hand, the conversion of an old laboratory, wa
house, mansion, or garage into an up-to-date industrial resear
laboratory may entail a number of limitations and hazards whi
could nullify the saving contemplated by retaining the shell of t
old building. Whatever the old building may have been used f
and whatever the materials and measurements of the shell may b
certain compromises in space, materials, and arrangement will
most certainly have to be made between what is desired and wh
has to be taken. In practice, the restrictions imposed by these co
promises have often proved to be more irksome than was anticipate
Finally, the purchase of an old building for a research laboratory
attended with the same risks as the purchase of any other secon
hand article, such as an automobile or a watch. Quite apart fro
its deterioration by aging or its devaluation through changing styl
and standards, the old building (or automobile, or watch) may co
ceal a number of faults which can be discovered only by actual us
The risk of such uncertainties may sometimes be well worth takin
but the possible gains and losses from the risk should be careful
balanced.

Costs

Since cost estimates for new industrial research laboratories hav
a way of pyramiding far beyond the modest expectations of the e
ecutive groups to which they are presented, a gauge by which pr
liminary costs may be estimated with reasonable accuracy seem
highly desirable. Fortunately, it is possible to obtain such a gau
from highly authoritative sources: the experience of existing indu
trial laboratories as to the floor area required per worker, and t
experience of builders as to the cost of laboratory space per squa
foot. The accuracy of such a gauge is made possible by the un
formity, which might be expected when strict budgets are bein
followed, of modern industrial research laboratory costs. As w
indicated in discussing the dimensions of a module, the net labor
tory area provided for a research worker varies from 150 to 35
square feet; however, when emphasis must be placed on housing
equipment, rather than personnel, as, for example, in physical tes
ing laboratories, these figures rise sharply. The gross area, inclusi

of halls, offices, library, and the like, provided per research worker varies from about 800 to 1,500 square feet; typically, the net area provided is 250 square feet and the gross area 1,100 square feet per research worker; the gross area is often 500 square feet for every person on the staff.

It would be most difficult, at the present time, to estimate the cost of laboratory area, were it not for the careful records of the building market kept by a well-known firm of builders who prepare an annual index of building costs and are able, in this way, to make cost comparisons among buildings they erect. Based on their 1944 index for the New York city area, the cost range of economically designed laboratory space was from \$8.70 to \$11.80 per square foot, averaging \$10.20. The building budget may therefore be taken, for preliminary purposes, as \$11,200 per professional research worker. It may further be estimated that laboratory furniture for an average module would cost \$3,000, and that an average inventory of apparatus, both special and stock items, would be \$3,800 per research worker. Thus the total investment in building and equipment per research worker, in a general research laboratory, is of the order of \$18,000. When large-scale testing or pilot plant facilities are added, an investment of \$25,000 per research worker may be exceeded. Many industrial concerns have, of course, commenced a research program with a smaller investment per worker, but managements considering committing their businesses to a research program must be prepared eventually for this range of investment in research *per se*. If the research workers are successful, moreover, the eventual investment in the fruits of research will be many times greater.

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CHAPTER XVII

The Tools of Research: Instruments and Supplies

In this chapter we discuss, in general terms applicable as far as possible to all kinds of industrial research laboratories, the most important problems and practices in connection with equipping the laboratory with adequate numbers and kinds of instruments, furnishing needed consumable supplies, making these instruments and supplies readily available to the research worker, and controlling and accounting for the expenditures involved.

How Much to Spend for Instruments

The decision regarding the amount which the research laboratory should spend for instruments may be viewed as a choice between more rapid progress with more instruments or slower progress with fewer instruments, with the same working force in either case. While this approach may be a desirable one for short-range planning, because short-term changes in total research personnel are rarely practical, it does not provide a basis for determining an optimum instrumentation, because continuing purchases of instruments will continue to increase output, to some degree at least, far beyond the point where such increase in available instruments is an economical way of obtaining that increased output.

For long-range planning, a more useful approach to the question is this: How large a portion of the total amount of money which is available to operate the laboratory should be spent in purchasing instruments and equipment and in paying for instruments and equipment already purchased? This is a question of the relative

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effectiveness of expenditures for capital goods or for labor and the availability of such goods or labor, since over a considerable range of circumstances the desired results may be obtained either with additional or better-trained research personnel without certain instruments, or with fewer or less expensive personnel and more instruments. It must be remembered, however, that this equivalence of instruments and personnel is valid only in a general way and is not by any means applicable to many individual cases. Some research results would never be obtained without the availability of certain instruments, and no amount of instruments and equipment could replace the research scientists and engineers who plan the work and evaluate the results.

The question of instruments versus personnel in the research laboratory resembles the question of tools versus labor in a manufacturing enterprise. In both cases the answer must depend on the available supplies of capital and capital goods and of suitable workers, and upon relative costs which are affected by the available supplies. In the war situation there was a shortage in both capital goods and labor, so that the proper course was to utilize all of each that could be obtained. In a peacetime economy, however, the shortage in capital goods is likely to be relieved sooner than the shortage in research personnel, since instruments can be produced more quickly than research workers can be trained. Thus the trend is likely to be toward greater relative expenditures for instruments and equipment.

The proper balance between expenditures for instruments and for salaries and wages must depend on the type of research to be done, whether exploratory or applied, and on the field of science or industry which is involved; just as the relative amount of capital investment in a manufacturing plant depends on the product to be manufactured.

Furthermore, the proper amount to be spent for research tools must be expected to change with time. The world seems to be steadily becoming more mechanized, and all activities of life seem to call for more and more capital goods. Research is not likely to be an exception to this general trend, particularly since research, by its very nature, is always broadening its scope.

The proportionate amount to be spent for research instruments and equipment is not susceptible to experimental determination, r is it possible to evaluate numerically the results of any given strumentation ratio because of the basic difficulty in placing a merical value on research itself. Therefore, the decision is a atter of judgment which must be developed through experience keen observation of all aspects of research. Certain records, re-ting to the extent of use of certain instruments and to specific un-led needs for other instruments may be kept to aid this judgment, t research operations are so varied as to defy comprehensive alysis.

The decision regarding the size of the budget for instruments d supplies is usually made at the higher levels of management. he persons involved in the decision are usually very conscious of e cost of instruments, although they may not be so directly fa-iliar with the intangible cost of doing without instruments—the tangible cost arising from ineffective utilization of research per-onnel and from limitations in the scope of investigations which nay be undertaken. Hence their judgment is likely to err on the ide of spending too little. Probably only rarely has too much been ppropriated for instruments.

On the other hand, if the decision were made at the lowest level of supervision, by the research project leader, who is closest to the actual use of the instruments, the error might readily be on the side of spending too much for instruments. In fact, to those responsible for the business side of research laboratory operation, the demand of the research worker for more instruments seems limitless. The tendency in this direction is only natural, since the research worker himself is directly aware of how he has to wait, improvise, or replan his work because certain instruments are not available and he is only remotely concerned with the problem of balancing the budget. If the responsible research worker were made to realize the limitations in the amount of money available to operate the laboratory and that, with a fixed income, more instruments mean lower salaries, a limit would be placed upon his estimate of his needs. If he is given sufficient information about the business side of the matter, his judgment regarding requirements for instruments and equipment should develop reliably, and should be given important weight in deciding upon the budget.

Certain instruments are so complex, expensive, and specialized in application that only the largest research laboratories can justify having them, and no laboratory would want more than one of a kind. Other instruments should be available in every laboratory in a particular field, though rarely would more than one of a kind in each laboratory be required. Still other instruments are of such general utility and low cost that every laboratory in a particular field should have one, and the larger laboratories will require many instruments of each type. Finally, certain instruments are used so steadily and are so inexpensive that every research worker in a particular field should have one for his own use. Thus a portion of the budget for instruments will tend to be independent of the size of the laboratory; another portion will tend to proportionality with the size of the laboratory; and a third portion will increase with the size of the laboratory, but less rapidly than that corresponding to strict proportionality because of a diversity effect. The larger the organization, the less the total demand for the use of a given type of instrument will fluctuate and therefore the possible efficiency of

PHOTO. 29. Measuring the optical properties of glass. (*Courtesy of the Bausch and Lomb Optical Company.*)

tilization will be greater. This means that the relative cost of nstrumentation is inherently less in a large laboratory, and that he cost for instruments may be so great in some fields as to make eparate research laboratories of less than a certain minimum size impractical in those fields. Furthermore, this suggests that the proper alance between expenditures for instruments and for salaries may epend on the size of the laboratory, since the versatility needed by he small laboratory may be obtained better with all-round men than with instruments.

To Buy or Build?

The first question which must be decided in planning to meet a particular instrument need is whether a commercially available instrument will be satisfactory or whether a special instrument must be developed for the purpose. The considerations which will influence this decision are discussed in the paragraphs which follow.

The development of a new type of instrument or piece of laboratory equipment may be a proper research project, particularly if the laboratory is active in the instrument field. Such a development should be undertaken on this basis if it meets all the criteria for the selection of other research projects. If it is undertaken primarily to provide equipment for the use of the laboratory, this should be recognized as a diversion from the normal business of the laboratory, which will be advisable only under special circumstances.

If the new type of instrument is urgently needed in the work of the laboratory on another project, the development of the instrument may be undertaken as a part of that project, if no other way of obtaining it is available. However, this may make the cost of the project needing the instrument excessive compared with what the cost would be, if the instrument were developed in a laboratory such as that of an instrument manufacturer, where special skills would be available and where broader utilization of the instrument development could be obtained.

When pioneering in an entirely new field, the development of measuring instruments and techniques is likely to be an inseparable part of the research program. For example, in exploring the usefulness of each new portion of the radio spectrum, new kinds of signal generators and power-measuring equipment must be developed. Such pioneering with instruments and methods is truly research and a proper undertaking for the first worker in any field. Care should be taken, however, as the field is developed, to transfer responsibilities for research on instruments to the proper groups, within or without the laboratory, at the earliest practicable point, in order to minimize the preoccupation of the pioneering research workers with instrument problems.

PHOTO. 30. Research on optical instruments which employ electronics. *(Courtesy of the Bausch and Lomb Optical Company.)*

It is important to co-ordinate well whatever work on instruments is undertaken in the research laboratory, in order to prevent duplication of effort and to encourage the working out of desirable measurement standards. The wartime organization of research was very effective in providing such co-ordination between laboratories.

The construction, in the research laboratory, of instruments and equipment which have already been developed and made available by others is obviously not research. Only the most extreme circumstances, such as unreasonable price, very slow delivery, and most urgent need, would justify the duplication of a commercially available instrument.

The construction of instruments and equipment in the research laboratory is sometimes the research worker's method of evading the effect of a refusal of the management to purchase the equipment, or his escape from what he considers intolerable delay or red tape in instrument-purchasing procedures—it may seem to him the only way e can get on with his research. The cost of the instrument is lost n the cost of a research project. In general, a large intangible cost is incurred instead of a smaller tangible one. If the research worker is sufficiently aware of the entire cost of his research, and responsible for it, and if procurement practices are reasonable and workable, this undesirable condition should not occur.

To summarize, buy instruments if possible, but if it is necessary to build them, recognize the non-research part of the work and take steps to minimize it, just as one would resist other temptations to divert research personnel from their proper functions.

Policies Regarding Purchase of Instruments

The procurement of suitable research laboratory instruments and equipment requires close co-operation between the technical personnel who are to use the equipment and those in the organization who do the purchasing. It is fortunate if the purchasing agent for the research laboratory has had research or engineering experience, since thereby he will be able to understand better the research side of the problem.

The purchasing group will wish to obtain competitive quotations from different suppliers of more or less equivalent instruments, in order to obtain the best price or delivery date. It is important, however, that this procedure should not result in the purchase of equipment which is unsatisfactory to the research personnel who must use it.

The research project leader must decide on the suitability instruments required for projects or investigations under his direction. In general, however, he will not be able to furnish complete specifications. Usually a research worker will have confidence in an instrument because of experience with it or with other instruments by the same maker. He will be justified in insisting on such an instrument, although another instrument might prove equally satisfactory, if time were available to prove it. One should not gamble with the trustworthiness of research results by using untried instruments.

The best instruments are the least expensive in the long run. Poor instruments which result in wrong answers may prove very expensive. Falsely encouraging answers may lead to further unproductive work, and wrong, discouraging answers may lead to the abandonment of an actually fruitful line of research.

Although the preferences of individual research workers should be followed as closely as possible in the selection of instruments and equipment for the research laboratory, it is desirable to give some thought to standardization in the choice of items which are provided in considerable numbers. When additional instruments of certain general types are needed, it is preferable to purchase types which have already been in use in the laboratory, if the performance is still satisfactory, because the research workers are already familiar with the characteristics and limitations of these instruments. If different models are obtained, it should be for a definite reason and not just a matter of change. In deciding upon what instrument designs to favor in working toward such standardization, it may be desirable to obtain the recommendations of a representative group of the more experienced research workers, in order to eliminate the purely personal preferences of individuals from consideration. In the foregoing discussion, instrument models have been considered which provide substantially the same performance. Of course, as many different types of instruments having different performance should be provided as are needed for the research to be done.

There is another form of standardization which is desirable with regard to research instruments. This matter will usually have been taken care of by the maker of commercial instruments, but it may be overlooked when instruments and equipment are built in the research laboratory for its own use. It has to do with the form, terms, or units in which the tests or measurements by the equipment are expressed. It is important that experimental results be obtained in such terms that they can be compared with the results of others, in that particular laboratory and in other laboratories. Progress with individual projects and the state of the art both will be enhanced by standardization of measurement techniques and instruments to accomplish this. Such standardization does not stifle research, but advances it by giving it a common denominator of ready scientific comparison and evaluation.

In the research laboratory it is difficult to anticipate needs because, in the nature of the experimental method, the details of the next experiment cannot be determined until the results of the preceding experiment are available. In the industrial research laboratory, however, every reasonable effort must be made to anticipate the need for instruments, so that the necessary expenditures may be budgeted in a businesslike way and so that slow delivery schedules of instrument suppliers will not delay the research. The intuitive judgment of experienced research supervisors will be most helpful in this. It must be expected, nevertheless, that in many cases anticipation will not be possible without extravagant and wasteful expenditures. It is necessary, therefore, to provide amply for contingencies when setting up the budget for instruments, and to establish channels for the purchase of instruments with as little delay as possible.

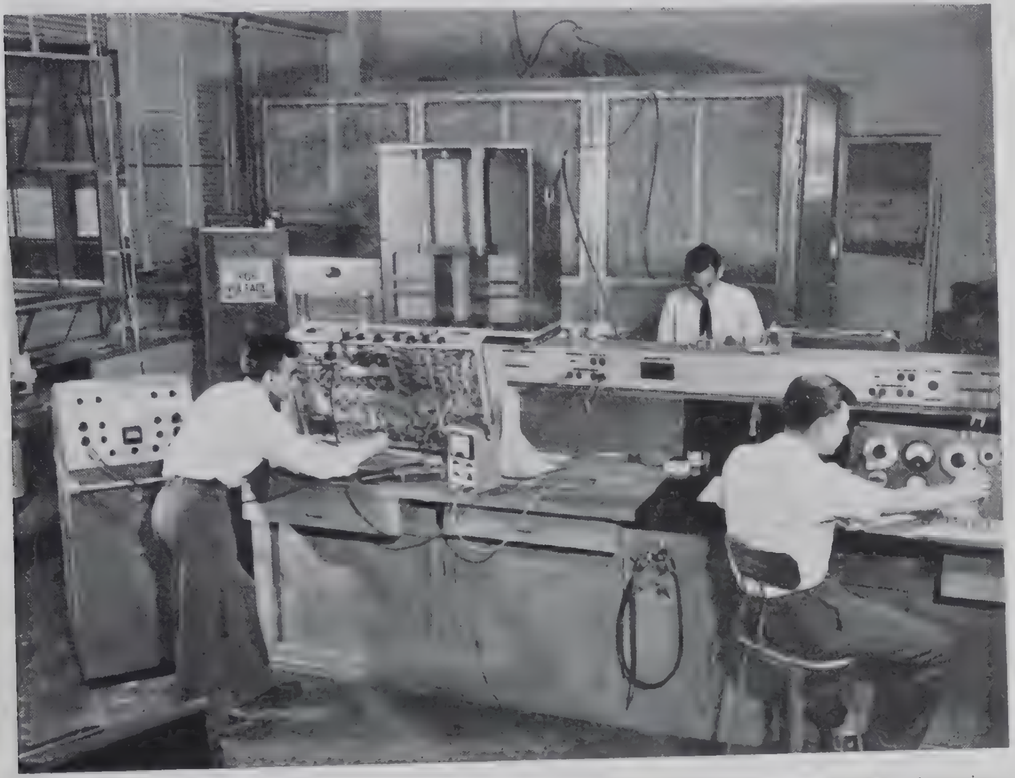

PHOTO. 31. A typical radio laboratory. *(Courtesy of the Radio Corporation of America.)*

Keeping Records of Research Instruments and Equipment

It is usual to provide an instrument stockroom, where instruments are kept when not in use. This stockroom lends the instruments to individual research workers needing them, holding these individuals responsible until the instruments are returned. The instruments are to be returned to the stockroom as soon as the immediate need for them is past. The stockroom will keep records, by card file or otherwise, of the characteristics and current location of all instruments and movable items of laboratory equipment, and will maintain a complete file of instruction books for all the instruments. In most cases the stockroom will also calibrate the instruments and make minor repairs. In theory, such an arrangement should provide for maximum availability of instruments to all and the greatest efficiency of utilization.

A number of difficulties arise in practice, however. Most of these difficulties lead to the same result: the instruments are not returned to the stockroom promptly and the theoretical advantage of the common stock is lost to a corresponding degree. The tendency is cumulative. When instruments are not returned to the stockroom promptly, the adequacy of the stockroom supply is reduced and research workers may have difficulty in obtaining instruments from the stockroom when they want them. Having once had this difficulty, the research worker is naturally reluctant to return an instrument, for fear that he may be delayed when he next requires it.

Another cause for reluctance to return instruments to the stockroom arises from lack of confidence, on the part of the research worker, in the reliability of instruments as they are issued by the stockroom. This is in part due to lack of confidence in the ability or reliability of the instrument stockroom personnel and in part due to distrust of the care which other research workers give to instruments they obtain from the stockroom.

A third reason for slowness in returning instruments to the stockroom is inertia. Research workers want to do research and do not like to carry instruments back and forth from the stockroom.

As a result of the practical limitations of the instrument stockroom system, its methods of operation may be modified to include the permanent assignment of certain instruments to particular research groups or individuals. These may be instruments which are in greatest use, instruments which have been obtained specifically for work done by that group or individual, instruments which will be rarely required by others, or instruments which are so critical in operation as to be unsuited to use by others or maintenance by the stockroom. It will usually be desirable for the stockroom to keep records of this permanently assigned equipment, although responsibility for the calibration and maintenance of such equipment will naturally rest with those to whom it is assigned.

While permanent assignments are obviously desirable in extreme cases, there are a number of disadvantages in the too general use of such assignments. In the first place, more instruments will be required. The cost of these must be considered relative to the cost of better stockroom facilities to make temporary assignments more acceptable and to the cost of research time lost because of unavailability of instruments. Secondly, the encouragement to order instruments for a particular project in order to obtain permanent assignments, when such instruments will be of general utility, may improperly inflate the cost of certain research projects. Thirdly, storage facilities in the individual laboratories may be severely taxed if there are too many permanently assigned instruments, and the provision of more storage space may seriously restrict the research usefulness of the laboratory space.

If the instrument stockroom is to be more than a repository for instruments which nobody wants, it is essential that it be in charge of a person of real ability and adequate technical training. It is not a job for a boy, a clerk, or a technically trained person who is lacking in initiative or in ability to get along with others. Yet it must be recognized that special effort may be required to make the job attractive to a qualified person. It is not likely that a suitable person will be content to remain in the instrument stockroom indefinitely; therefore a promotional sequence should be laid out to insure a future for the job.

A convenient location is important to the usefulness of the instrument stockroom. In addition, it is suggested that making available inexpensive personnel as messengers to call for and deliver instruments would go a long way toward achieving maximum efficiency in instrument utilization.

The most important requirement is that the individual research worker have confidence in whatever methods are used to distribute and maintain the instruments of the laboratory. If he has this confidence, his co-operation will be assured, and most systems will operate satisfactorily. But if this confidence is lacking, evasions and inefficiency in the use of instruments will result. Furthermore, lack of confidence in the reliability of available instruments will impair confidence in the research results which are obtained.

Keeping the Instrumentation of the Laboratory Up To Date

Interest in new things is one of the outstanding characteristics of the research worker, and therefore he will naturally be interested in new instruments and measuring techniques. Thus the problem of keeping up to date on instruments is not likely to be a major one if the laboratory staff are really qualified for research. Some systematic effort, however, to keep the laboratory in the fore with respect to instruments will be well worth while.

To begin with, a comprehensive and up-to-date file of catalogs and other data relating to commercially available instruments should be maintained in the library or in the purchasing department, where it may be consulted freely by the research staff members as they plan their work.

An important way to keep up to date is through active participation in the work of standardizing committees in technical organizations. Contacts with the leading suppliers of instruments are also good sources of information about instrument developments. Many instrument makers have catalogs and periodic publications describing in considerable detail the latest types of instruments.

Contact with other research organizations often produces ideas and information on measuring equipment. Reports on research usually describe the instruments used. Useful information on instruments for related research projects is often obtained from such reports.

A comprehensive survey of the scope, efficiency, and adequacy of the laboratory facilities for measurements and tests might be made periodically. Such a survey, conducted by a representative committee of research workers, selected for their judgment and perspective in research planning, should be of material assistance in noting trends in instrument requirements and in anticipating basic needs.

Instruments and Equipment—Accounting and Budget Practices

It is customary to treat the cost of instruments and tools as a capital asset cost—that is, the initial costs are accumulated in a capital account and charged to operating expense as depreciation, in installments over the useful life of the equipment. In establishing the depreciation rates to be used in amortizing instrument costs in current laboratory operating costs, it is suggested that particular recognition be given to the factors of obsolescence, inadequacy, and supersession, since with laboratory equipment these factors are generally more important than ordinary wear and tear in use. The very nature of research is to bring about obsolescence and the tools it uses do not escape this result. Progress in research in a given field may bring about the necessity for replacing certain testing equipment after a period of use so brief as to seem incredible to one not familiar with research.

Bulletin "F" issued by the Internal Revenue Bureau of the U. S. Government indicates the depreciation rates which are allowable for tax purposes for various classifications of facilities. Generally the rates indicated are based on average life expectancies under normal operating conditions. When the use is in a research laboratory, the life expectancy in some classifications may be much less because of the greater influence of obsolescence. This has been clearly shown by the detailed studies made of the actual experience of a representative research laboratory in the electronic field. The rapid advances being made in this field brought about the accelerated obsolescence of research equipment used by this laboratory. The same rapid obsolescence very likely occurs in other rapidly moving research fields.

The following tabulation indicates the allowable rates for tax purposes for several classifications of facilities which are typical for many laboratories, together with rates corresponding to what actual experience may be for laboratories operating in fields where rapid obsolescence of equipment is to be expected.

	Life Expectancy—Years	
	Bulletin "F"	*Possible Where Obsolescence is a Major Factor*
Machinery	20–25	15
Electrical Apparatus	17–20	10
Test Equipment	15	7
Meters and Measuring Equipment	10	5

The need for adequate fixed asset accounting records, particularly for income tax purposes, is becoming increasingly more apparent. As the above figures suggest, tax savings are possible through the proper segregation of machinery, electrical apparatus, test equipment, meters, and measuring equipment in these records. When laboratories have such assets in substantial amounts, the cataloging and tagging of all pieces of equipment and the maintenance of supporting records in detail by the accounting department may prove profitable.

Apportioning the Budget

The determination of the total amount to be budgeted for instruments and equipment has already been discussed in the preceding pages. The apportionment of the available sum to specific items and for specific research projects or research groups will be considered in the following paragraphs.

Many laboratories have found that the operation of a budget procedure similar to that outlined below can be effective in the management and control of laboratory instruments and equipment acquisitions.

1. Preparation, by individual research groups, of lists and descriptions of facilities which they believe will be required during the budget period for each group. These lists should indicate the major items individually, together with estimated costs. Small-cost items may be combined for this purpose.

2. Preparation of a summary budget which includes comparisons with past experience for all research groups involved. This should be carefully reviewed by the laboratory management, considering benefits to be obtained, cash available for the projected purchases, and comparison with prior years' expenditures. Approval of the research director, the chief executive of the company, or the board of directors is usually required before the budget for instruments and equipment, in its final form, is put into effect.

3. Critical review of each item proposed for purchase during the budget period, at the time it is to be ordered. Order forms should call for an accurate estimate of cost, and each item should be closely checked for possible duplication of equipment already available, for urgency of need, and for accounting treatment. In doubtful cases, research supervisors should be required to justify their recommended purchases.

4. Preparation by the accounting department of a monthly summary statement which indicates for each research group the amount appropriated together with the amount of commitments for purchase or construction and the balance remaining.

Materials and Supplies

In the modern research laboratory, materials and supplies are needed for the construction of models, experimental apparatus, and specialized equipment, and also in conducting tests and experiments. A mistake too often made is that of attempting to apply to these materials and supplies in the laboratory various inventory control systems which are successfully employed in manufacturing or other industrial activities. An essential feature in the management and control of research materials and supplies is that they be readily available and easily accessible to the research worker, so as to prevent the possibility of costly research time being spent following cumbersome material inventory or control policy.

The materials and supplies required to be stocked by a laboratory generally can be classified in three major groupings:

1. *Raw materials* (without any processing or fabrication).
2. *Finished stores* (small components, assemblies, and finished parts).
3. *Operating supplies* (miscellaneous—dependent on field of research).

The amount of inventory to be maintained for each classification is dependent on the type of laboratory and special conditions surrounding each case.

It is preferable to have one or more conveniently located storerooms, in number related to the size of the laboratory, each of which contains a representative stock of all materials and supplies, rather than separate stockrooms for each of the above groupings. The stock should be so arranged as to make identification and selection a matter of mere "window shopping." This accomplishes two primary purposes:

1. The research worker can be assured of obtaining complete satisfaction in material and supplies from one conveniently located source.

2. Storage in full view tends to advertise the contents of the storeroom and aids in formulating decisions in the mind of a research worker when the exact nature of his needs is not entirely crystallized in his thinking.

The many problems of procurement, quantity economy, and bulk storage should be centered in a main stockroom. The conveniently located local stockrooms can all be serviced and supplied by the master stockroom. Thus only one stockroom attendant is needed for each local stockroom, and the personnel in the main stockroom operate at maximum efficiency, since they are not encumbered by the disbursement of small quantities of individual items. Likewise, all detailed records necessary for the proper accounting for stores of materials and supplies can be kept in the main stockroom, thereby allowing the local stockroom attendant to devote much more time to serving the research workers. Stock can be so arranged as to permit "self-service" by the research workers; such arrangement will be particularly advantageous for items for which no accounting is made. "Full view" storage, "self-service," and a minimum of record keeping by the attendant will greatly speed up the disbursing of stores at the local stockrooms.

It is generally neither feasible nor desirable to maintain a tight requisitioning system to disburse many of the materials and supplies used in the laboratory. Although the cost of materials and supplies is usually a comparatively negligible element in the cost of the average research project, and although most research personnel consider any paper work in connection with the control of stores so much red tape which hinders their productivity, it is nevertheless sometimes necessary or compulsory to control and record the use of certain materials. The materials-control procedures of the laboratory must be adequate to furnish such data as costs for the proper valuation of inventories, verification for quantities and value of materials used in the construction of specialized capital equipment, and substantiation for quantities and value of materials used in work under research and development contracts of the various governmental agencies.

The principal conditions and requirements to be met in the control of materials and supplies in the research laboratory are:

1. Some items must be dispensed rapidly and without recording. This applies to all materials and supplies of negligible value.

2. Other items, due to their nature, usage, or value, must be controlled and recorded as dispensed.

3. An inventory pricing or valuation procedure must be established compatible with both (1) and (2) above, and yet assuring sound costs and investment valuation.

Once the various materials and supplies have been classified under (1) or under (2), the consumption of items of negligible value can be estimated periodically and considered as overhead expense.

Yearly physical inventories will permit an adjustment between actual and estimated consumption. The materials and supplies which are requisitioned from stores can be charged directly to the projects concerned, and inventory quantity and value reduced currently. Always, however, the question arises as to what prices are to be used in charging projects and in valuing physical inventories. The periodic-average method of pricing inventories offers a good answer to this question. This method of pricing is a variation of the weighted-average method, but instead of computing an average unit cost after each purchase, such computation need be made only at the end of each predetermined period. In the business of research, such period need never be shorter than a quarter year, and experience shows that a longer period can be successfully employed.

The principal advantage in using the periodic-average method is that it eliminates much of the clerical detail required in the operation of other standard inventory systems. Materials and supplies can be priced at the prevailing average price; it is not necessary to identify issues of materials with particular quantities purchased or received. Costs are applied to all projects similarly on an equitable basis. If it proves impracticable or undesirable to value the inventory investment on the "cost or market" basis at the year end, there are available data which permit a valuation acceptable to both research and financial management.

The principle and operation of this pricing method is expressed in the following formula:

$$U = \frac{V_i + V_p}{Q_i + Q_p}$$

Where U = Periodic-average unit cost
V_i = Value of inventory at beginning of period
V_p = Value of purchases for period
Q_i = Quantity of inventory at beginning of period
Q_p = Quantity of purchases for period

Having up to this point discussed principles and considerations affecting the solution of instrumentation and supply problems which arise in research management, it would be logical and helpful to conclude with numerical examples. It has not been found practical, however, to represent the wide range of industrial research activities in a sufficiently small number of typical cases. It appears that little uniformity has yet developed in research procedures and practices in

different fields of research or in different industries. This may
due in part to the inherent diversities in research itself, and in pa
to the relative newness of research as an industrial activity. T
non-uniformity of practice involves not only the research metho
themselves, but also the terminology used in describing them an
the accounting systems used in recording and controlling the e
penditures involved. It thus becomes a very complicated matt
to compare fairly and quantitatively the operations of any two r
search laboratories. This chapter on research instruments, equi
ment, and supplies is therefore reluctantly brought to a close withou
numerical examples, since it appears that any figures which might
included would fall so far short of being completely representati
as to be more misleading than helpful.

CHAPTER XVIII

The Research Man's Helpers: Service Personnel and Facilities

Services discussed in this chapter are all essential to the successful prosecution of research work. Because of their specialized nature, they are best rendered by separate units distinct from the research laboratory proper, but the facilities for these units should be located conveniently near the research laboratory. Close liaison must be maintained between the research men whose immediate needs are to be served and the individuals performing the services.

The principal objects in establishing auxiliary services are to relieve the research man of tasks for which he is not particularly suited, and to insure that important and intricate operations essential to research shall be economically and efficiently carried out. Often it may appear in a well-run research laboratory that the research worker is being pampered. If this is so, it is because there are jobs which he alone can do and should be allowed to do without wasting his time on other things, and because these other things—which are called "services"—may be done better by other persons.

For example, many technical men have a rudimentary knowledge of machine-shop practice and glassblowing. Generally, however, these skills are not so developed as to enable them to compare favorably with skilled artisans. To attempt to develop such skills would necessarily divert their attention from research problems. As another example, any research man should be able to keep abreast of the literature in his own field, but a group of research men can often do more effective work if aided by technical librarians and translators.

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Whether the auxiliary services are carried out by one or a few individuals or by organized units of personnel will depend upon the size of the research laboratory. In a large laboratory, it is more difficult to decide whether the personnel responsible for auxiliary services should be distributed over the various research units or should constitute central units providing services to all members of the research staff. Many have found that these services are better and more uniformly provided by the central unit plan of organization. Occasionally, exceptions to this do exist. For instance, even with a central stenographic pool, certain members of the research organization will continue to need full-time secretaries. Again, certain collections of books in highly restricted fields may properly belong in some individual's office instead of in the library. But these cases, and others like them, should be regarded, at least in a large organization, as definite exceptions to the general principle that efficient services can best be given by central organization and by pooling of personnel into specialized units devoting full time to service jobs for the entire research staff.

Services upon which a research man depends may be conveniently divided into *technical* and *nontechnical*, though the line between the two is not always easy to draw. Those of a technical nature include the services of an analytical laboratory, metallurgical laboratory, laboratories and set-ups for physical testing of products, and the technical library and translators. Nontechnical services include those of the machine shop, glassblowing shop, photographic laboratory, and storeroom and stenographic services.

Technical Services

Some of the most important assistance given to the research man requires technically skilled personnel. In units rendering this kind of service, work is performed which, in its way, is just as scientific as that of the research man and which frequently requires as much training and imagination as that employed in research proper. The kinds of technical aid given to the research man vary, of course, with the nature of the scientific work under way. Some laboratories will have frequent need for quick metallurgical analyses; another may need X-ray data for the identification of crystals; still another may require results of toxicity studies. It is safe to say that a large laboratory, from time to time, will require results which can be obained only by skillful personnel in well-equipped laboratories for netallurgical analysis, chemical analysis, physical identification, determination of physical properties, testing materials under use conditions, toxicological testing, and the like. It is not feasible to have ermanent laboratory set-ups for all possible eventualities; consequently the less frequent types of technical services can be most economically rendered by outside laboratories. The more-often used services should be provided from within the laboratory organization. Thus a laboratory devoted to research on insecticides would certainly have a toxicity laboratory, but probably not a metallurgical laboratory.

Laboratory managements cannot be too careful in the selection of personnel for technical services. There is sometimes an opinion among young research men that service work, such as analytical or literature research, is on a "lower level" than some other types of research. The number of persons in technical services who wish to shift to research proper will be high; they may feel that they cannot climb in the company unless they shift to research directly connected with the products of some department of the company, and that they have no opportunity to obtain patents. Companies should attempt to dispel such notions by maintaining the same salary scales and promotion schedules in all laboratories, and by emphasizing the essential contribution the analytical and testing laboratories and the library make to the progress of research. Technical men in these lines of work, it may be pointed out, have a better opportunity than other research men to publish their results, and this opportunity will often appeal strongly to the ambitious scientific worker.

In this section, descriptions cannot be given for all of the service laboratories used to advantage by industrial research organizations. Consideration in detail will be given for only two which are probably most generally useful to a wide variety of research organizations. They are an analytical laboratory and a technical library.

Analytical Laboratory

An analytical laboratory is an integral part of a research organization working in the chemical field. This group should consist of trained chemists, technicians, and laboratory assistants organized to carry out the many types of chemical analyses necessary. Such a laboratory has three principal functions:

1. To analyze samples by well-established methods.
2. To develop analytical methods as they may be required.
3. To act as a reference laboratory or "bureau of standards" for plant control laboratories.

In line with these functions the analytical laboratory may be set up in three sections: standardized analyses, methods development, and laboratory standardization.

PHOTO. 32. Analytical laboratory—development of new methods. (*Courtesy of the Hercules Powder Company.*)

The standardized analyses section carries out determinations and performs chemical analyses for which standardized methods are available. In general, these comprise the major portion of the work of analytical laboratory. It may be headed by a general supervisor sponsible to the head of the analytical laboratory. It may be furer subdivided into small units each of which covers a specific limed field of work, each unit headed by a working supervisor who is chemist trained in the methods of his particular field.

While the general supervisor of the section takes care of the overll planning and distribution of work, selection of equipment, and arious administrative duties, it is the working supervisor who mainins close contact with the people submitting samples for analysis. Ie is familiar with the research chemists' problem, is able to deternine the peculiarities of the samples and whether any special hanlling may be required, and can pass this information along to the ndividual analyst best qualified for the work. He can also carry out pecial analyses and investigate specific points.

Wherever possible, recognized standard methods should be used o that the results are comparable with those of other laboratories. Equipment that is used frequently should be set up and kept in readiness at all times. Special reagents and standard solutions frequently required should be prepared in quantity and stored in bottles connected to dispensing apparatus. The standardized analyses section should be essentially a production unit for prompt and accurate analysis of samples.

The purpose of the methods development section is to keep abreast of the rapidly changing field of analytical chemistry and also to enable the analytical laboratory to keep pace with the work of the research organization. It is desirable to have a section of this type in the analytical laboratory rather than to use technical personnel from other groups, because the development of analytical methods is best done by individuals who are specially trained for such work and are familiar with practical applications. This unit should be composed of persons with advanced chemical training, some of whom have specialized in analytical chemistry and who have had considerable experience in chemical analyses.

When the development work on a method is nearly complete, a chemist from the standardized analyses section may be assigned to work with one from the methods development section in order to become familiar with the new method and to facilitate its routine use. Members of the standardized analyses section may be assigned, at times, to assist the research men of the methods development section. Those assigned to analytical research, however, should not b shifted to standardized analytical work except in an emergency.

The laboratory standardization section may be considered th "library" of the analytical laboratory. It should maintain a con plete file of all the laboratory's methods, the control methods use by the plant laboratories, and standard published methods such a those of the American Society for Testing Materials and Associatio of Official Agricultural Chemists. New methods which will be use frequently should be written up in standard form and included i a laboratory manual. Such a manual may contain detailed pro cedures for hundreds of separate determinations. The method should be revised as the need arises, and should be in sufficient de tail for the average chemist to follow without resorting to additiona references. Specifications should be reviewed constantly to see tha sufficiently critical tests are available to insure proper quality of th specified materials. This section may also send out check sample of representative materials to all plant laboratories for comparativ analyses. Results outside established checking limits should be fol lowed by this group to determine the cause of discrepancies and t apply the necessary corrective measures.

With an analytical laboratory organized along these lines, it i possible to develop analytical methods for the materials prepare by the research chemist, to analyze these materials, to handle th control analyses as they pass through the pilot plant stage, and t devise and standardize rapid methods for use in plant control lab oratories in the large-scale manufacture of these materials. Prope attention may be given to the varied demands of the research chem ist for chemical analysis and the development of new methods, o the process supervisor on "trouble-shooting" problems, and of th plant superintendent for strict and uniform control.

Technical Library

The primary function of an industrial library is to pass on t the users important information necessary in their work. Only fo this purpose does it serve as a storehouse of literature. The service of the library consist in getting information quickly, in a convenien and usable form, to the person who should use it. The efficient sci entific library will often serve its function only if it takes the ini tiative in sending information to the right person at the right time

It must store books, periodicals, documents, photostats, microfilms, patents, reports, and sometimes technical correspondence; material must be easily found, and often it must be condensed or translated from foreign languages.

Information in an industrial library is found in the published literature and in reports, correspondence, and other unpublished documents which are the confidential property of the company. While the published literature of a library may contain thousands of books, journals, and patents, the primary aim should be to assemble only material of intrinsic value in the specialized fields of research in which the company is interested. A collection larger than needed shows poor selection and is an added item of expense. Therefore great care must be exercised in the purchase of books, in eliminating unnecessary publications, and in organizing the selected material for efficient use. Decision on these questions should be based upon a knowledge of the actual and potential interests of the company, on sound knowledge of the relative values of various publications, and acquaintance with the holdings of neighboring libraries with which interlibrary loans can be arranged. Lists of new material added to the library ("Accession Lists") should be is-

PHOTO. 33. Library in the Whitemarsh Research Laboratory. *(Courtesy of the Pennsylvania Salt Manufacturing Company.)*

sued periodically to inform the users of the library as to what is available.

To aid the research worker in keeping abreast of his subject and to be cognizant of the work of others, the library staff must digest a vast amount of published information and make it readily available to the technical person in such a form that he can decide with confidence what he should take time to read in full, and what he can afford to pass over. Various schemes have been used to effect this purpose. With a small laboratory staff, for instance, marked copies of the journals may be circulated or sent directly to the individual who would be most interested in the material.

With a larger staff, this is too slow, and literature reference bulletins are more effective. In preparing this bulletin, the library staff should scan all of the material in current journals, abstracting the articles of interest, and publishing these abstracts and references in a mimeographed or printed bulletin. Patent references may be included in this bulletin; sometimes, however, it is better to issue a separate bulletin containing abstracts of new patents. Not only should the bulletin cite references available in the library, but also publications not regularly received but abstracted in the standard abstract journals. If a reader of a bulletin is interested in seeing an article referred to, he can request it from the library, and if necessary the library can obtain it as a photostat or microfilm, or borrow it. It has been found desirable to arrange the bulletin in such a way that individuals who receive it can cut out references which interest them and keep them in a suitable card file. Moreover, a card file of all of the references included in the bulletin is useful in the library itself for locating fairly recent articles which have not yet been indexed in the standard abstract journals.

Some services of the library staff are primarily for the individual. For example, a translator may spend full time assisting research workers. He may read translations aloud to the individual worker, but if the work is of widespread interest and importance, translations should be typed and made permanently available in the library. Naturally, of course, the more languages the translator knows the less dependent the library will be upon outside sources for translations. In general, German, French, and Russian should be the minimum qualifications of a translator. A translator should also have a good knowledge of the field in which he is working, otherwise the technical language used will be like another foreign language to him.

Literature surveys and bibliographies may be made either by the technical men who need the information or by members of the library staff. The former plan occasionally has some advantages in that the selection and evaluation of the information is made by a man working intimately in the field; in such cases the library personnel can give him considerable help in collecting the information, translating it, abstracting it, and the like. On the other hand, the preparation of a good critical survey of the literature requires talents which many competent laboratory scientists lack: good ability in verbal thinking, knowledge of and respect for books, critical ability in the interpretation of the written word, and—perhaps most important—an interest in writing. For this reason, extensive literature surveys can best be made by scientifically trained persons who devote their time to such work almost exclusively. The scientific library attached to a large research laboratory should therefore have a staff of one or more persons highly trained in the scientific fields in which research is being pursued, devoting themselves to "literature research" and making their knowledge of the literature available to those who can use it in planning further research work.

Surveys and bibliographies are usually made by the literature research staff at the request of research workers in the laboratory, shorter jobs being handled by the reference librarians. If information on some very specific topic is needed, results may be reported in a letter or oral report. If a general and comprehensive survey of knowledge in some fairly broad field is requested, the results should be written up as a formal report. Such a report makes it possible for the research personnel to obtain detailed knowledge of the subject as it exists in the published or confidential company literature. Appreciable time is saved and repetition of work already done is avoided. In order that this work may be better correlated with the research program, the literature research man should be invited to research conferences where projects are planned and evaluated.

Over a period of years a research organization will accumulate large amounts of scientific information preserved in large numbers of laboratory notebooks and volumes of typed reports. This information is extremely valuable and must be made available to research workers. Abstracters and indexers with technical knowledge of the field of work should be on the library staff to classify and index it. The same persons may also classify and index patents, journal articles, translations, manuscripts, and certain technical correspondence. If all this information is assembled in one card file, the research worker has ready access to the knowledge accumulated in past research.

In addition to the persons with scientific training who are occupied in these ways, the library must, of course, have a library staff proper. Library training is desirable for persons working in the library proper (stacks, reading room, etc.), but the consensus among technical library people is that training in the subject field is equally important. If it is not possible to employ a person trained in both library science and the subject field, it is better to take one with the latter training; library work can be learned on the job, whereas the subject field cannot ordinarily be learned in this way. If assistants in charge of the reading room and circulation desk are trained in science as well as in library work, they can offer considerable aid to the research man by making information quickly available. They can also save time for the scientific workers on the library staff by answering many reference questions which would otherwise go to the literature research group.

The library and translating staff thus can collect, integrate, and pass on to the research workers the significant and latest scientific information and reduce to a minimum the chances of repeating earlier work. The research worker is able to plan and evaluate his own work on the basis of this accumulated knowledge and can devote his full energies to productive new research.

A well-equipped library with personnel trained in both library science and in the subject field can undertake a variety of other jobs which must be done. What these jobs are, of course, will vary from laboratory to laboratory and even within one laboratory from time to time. Some things which seem most suitable as library responsibilities are: the editing of papers for publication, getting up-to-date information on scientific societies and their meetings, and collecting and collating instruction sheets, rules and regulations, and the like.

Other Technical Services

The two services described—analytical and library—are only samples of the numerous technical services required by large modern boratories. The problems of every laboratory are peculiar to it; e kinds of service groups it requires will depend upon the nature its scientific and technological problems, economic considerations, cation (i.e., proximity to other laboratories), size, and available personnel. What technical services should be provided by outside labratories, which ones should be given by centralized service groups ithin the laboratory, and which must remain the responsibility of ie individual laboratories within the over-all setup, are matters that an be decided only by the management of the laboratory. In a rge laboratory, however, economies will be gained by centralizing uch services; the costs per hour will be less and the task of making uch services pay their own way will be simplified.

In this chapter the authors have described some of the technical ervices with which they are familiar from first-hand experience. General principles of their organization and efficient functioning are applicable to other types of service groups. What has been said about the analytical laboratory and the technical library can be applied in general to other services required by other research organizations, e.g., statistics and calculating services, and laboratories for toxicity studies, metallurgy, pyrometry, soil testing, and strength of materials, and special laboratories for service operations unique to specific companies.

Nontechnical Services

Services of a nontechnical nature provide the research man with working materials, special equipment, and assistance in recording the progress and results of his work. While the size of a research laboratory may dictate the extent of these services, it is obviously inadvisable to expect a research man to improvise his own requirements along these lines. The research man cannot become a jack-of-all-trades and still perform effective research.

In small laboratories where specific needs such as that for repairing apparatus or erecting equipment may not require the full time of a single employee, it may be possible to share the facilities of a neighboring plant. In small research laboratories (employing less than twenty-five men) practically all of the mechanical work and glassblowing can be done by outside contractors who can be called in to repair all equipment or to whom plans can be sent for the building of new equipment. With larger laboratories, it usu-

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In small laboratories where specific needs such as that for repairing apparatus or erecting equipment may not require the full time of a single employee, it may be possible to share the facilities of a neighboring plant. In small research laboratories (employing less than twenty-five men) practically all of the mechanical work and glassblowing can be done by outside contractors who can be called in to repair all equipment or to whom plans can be sent for the building of new equipment. With larger laboratories, it usually is profitable to set up shops attached directly to the laboratories In a larger laboratory, more than enough work is regularly availabl to keep one machinist and one glassblower busy full time.

For carpentry, plumbing, and painting which are principally use in maintaining a laboratory rather than directly aiding the experi mental work, it is not feasible to set up a shop unless the laborator has a physical plant which is quite large, requiring sufficient mainte nance work to keep at least one man in each of these groups bus full time.

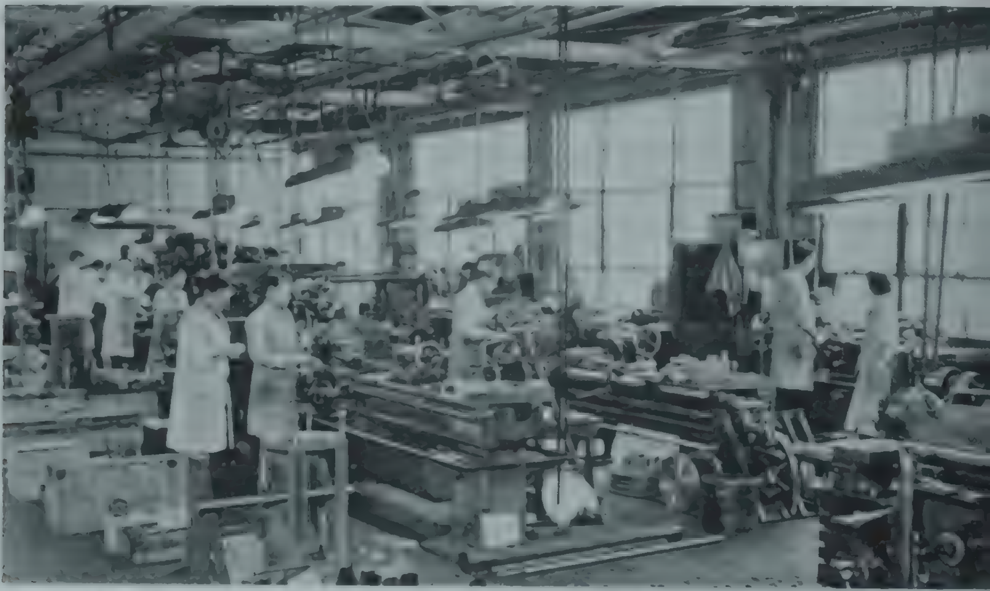

Photo. 31. A laboratory machine shop. *(Courtesy of the Hercules Powder Company.*

Machine Shop

The machine shop in a large laboratory may be only one unit o a shop setup; there may be such others as the electrical, welding, car pentry, pipe fitting, painting, and sheet metal units, each of whic has a separate shop to make any equipment required for laborator work. Experts are thus available who can be of considerable hel to the research worker, especially in designing and constructin equipment needed for experimental work. Often a good mechani is able to make suggestions for apparatus that might occur muc later, if at all, to the research worker.

The machinists employed in a laboratory machine shop shoul be the ones most capable that are available. Laboratory work is es entially nonrepetitive and requires a mechanic with unusual ability both to operate his equipment and to understand what the technical man requires. The latter is especially important since the echnical man usually has rather limited ability to draw blueprints of his apparatus. Such a machinist should be well versed in working with moderate-sized pieces of equipment and also with small, delicate precision types of instruments or machinery. Ordinarily, such a person is a machinist who has had a number of years of experience, including some in making instruments or handling precision machinery.

PHOTO. 35. Glass blowing shop. *(Courtesy of the Research Laboratories, Humble Oil & Refining Company.)*

Glassblowing Shop

A glassblowing shop is a facility which, in the majority of instances, cannot be provided in small laboratories because not enough work is available to keep a glassblower busy full time. In larger laboratories, however, it is more efficient and less expensive to provide the services of an experienced glassblower than to have each research man do this work himself. A craftsman in glassblowing not only relieves the research worker for tasks for which he alone is qualified, but often he may aid the research worker considerably by suggesting changes in the design of apparatus.

The glassblower should also be a specialized man who cannot only repair simple equipment but can also fabricate complicated setups. In small laboratories where there is not enough repair work and equipment fabrication to keep a skilled glassblower busy full time, it is often desirable to have him make, in his spare time, standard glass equipment such as spiral tube condensers which one would normally buy from an equipment house. But where there is a sufficient staff to keep a glassblower busy on special projects, it is undesirable to have him duplicate articles that are readily available on the market.

Other Shops

What has been said about machinists and glassblowers is applicable also to plumbers, carpenters, welders, and electricians. In larger laboratories, separate shops for each type of work will be needed. If a laboratory is large enough to require their services full time, they should hire the best and most experienced men available. This, again, is due to the changing nature of the work to be done and to the necessity for unusually high-grade work. In smaller laboratories where such work is done by outsiders, the same high standards of performance should be required.

Photographic Laboratory

The primary aims of a photographic laboratory are to aid the research worker in presenting to the best advantage the results of research investigations, to provide the assistance that photographers can give in the actual performance of research work, and to assist in the preservation and duplication of records.

The photographic laboratory aids the research worker in presenting pictorially and graphically the results of his work. It is possible, of course, for each research worker to illustrate his own reports, letters, papers, and other writings by graphs, charts, drawings, and photographs which he has prepared. But in most instances, it will be found that his time could have been spent more profitably on research and that the job would have been better done by a trained photographer or draftsman.

Photography is not only useful in the presentation of results but often plays a direct part in obtaining results in the first place. Much work of a physical character (for instance, X-ray crystallography, and spectroscopy) has photography as an integral part of the procedure, and of course, such photography should be done by the scientific worker skilled in the technique of these fields. Nevertheless, there are other cases where the professional photographer must be used; for example, in any tests which have not been standardized and quantified, photographs of the results are frequently the best methods for keeping records of them. Such photographs must be made under uniform conditions if they are to be validly compared, and this should be the responsibility of trained photographers.

Photo. 36. Photographic laboratory. *(Courtesy of the Hercules Powder Company.)*

A photographic group also serves a valuable function in duplicating records for legal purposes, for photostating documents which are not generally available, and the like. Occasionally, it may be desirable to photostat an article in a periodical instead of purchasing another copy or purchasing a photostat.

Only the third of these tasks can be successfully accomplished by a run-of-the-mill photographic technician. The first two require expert photographers, draftsmen, and artists; each job is unique and requires some understanding of what it is that the research worker is trying to get across. Consequently, not merely skillful technicians, but men and women of imagination and intelligence are needed for the successful functioning of a photographic unit.

Storeroom

The purpose of a storeroom is to keep in stock all items commonly used by research workers. In a large laboratory this may require several persons, full time. Articles should be available on request and arranged in good order. The storeroom loses its purpose if the research worker has to wait until equipment is found, ordered, or repaired. Thus, an adequate staff for the storeroom will probably consist of something more than merely storekeepers.

PHOTO. 37. A laboratory general storeroom. (*Courtesy of the Hercules Powder Company.*)

In the normal course of operations of a large chemical laboratory, many chemicals and pieces of equipment which cannot be carried as regular stock of the storeroom will be required for special projects. These items are usually ordered by the research worker through the regular procurement channels of the laboratory. If such special items are turned in to the central storeroom after use, they can be of use to others when needed in future projects. The storeroom must circulate lists of such equipment to those who may need it in the future, otherwise material may be duplicated, with consequent loss of time and extra expense.

The storeroom may also provide certain apparatus which may be borrowed by the research worker for the time needed. When the particular use is completed, the apparatus is returned to the storeroom where it becomes available to other research workers. Depending upon the over-all bookkeeping policy, the use of these instruments may be on either a rental or nonrental basis.

It is particularly this kind of equipment which the storeroom is responsible for keeping in repair. By taking this responsibility, the storeroom staff can save the research worker's time. They also can accumulate a valuable file of information concerning the comparative value of various makes of similar instruments. This file of information on past performances of equipment should be available to those who make out requisitions for new equipment.

In order to make this file of value and to make sure that the apparatus is kept in good order, it is desirable to have a person with technical training, especially an "instrument man," as supervisor of storerooms.

In a chemical laboratory, it is important to keep samples for future research and for legal purposes. These samples are probably best kept in a storeroom instead of in various individual laboratories and offices. In general, there will be very little borrowing of such material, but an excellent inventory and filing system for them is absolutely essential, especially since all the samples may look more or less alike and cannot be found even by a trained storekeeper without the help of a good inventory.

Stenographic Services

In general, stenographic services should be centralized in a main office. This is more efficient than a decentralized organization because it is easier to keep everyone busy full time. When a research worker wishes to dictate, he need only call the supervisor for an appointment and a stenographer is sent to him at the appointed time. If desirable, a Dictaphone or an Ediphone or similar equipment can be placed at his disposal.

In order to have a permanent record of all research work, a special group may type handwritten reports prepared by the research worker covering progress on and results of work carried out. Care must be exercised in typing and issuing these reports because they are a permanent record. Most technical reports are complex, and to type them requires some experience. Those assigned to this job usually should type only such reports, though they may also take care of miscellaneous related typing such as preparing technical papers for publication or presentation, and material for slides and stencils. Because of the technical nature of the material typed in a research laboratory, ordinary dictionaries and secretaries' handbooks are frequently of little use in making accurate and uniform copy. For that reason, it is necessary to provide typists and stenographers with formbooks containing word lists, approved nomenclature, and the like.

It is difficult to estimate the amount of clerical assistance needed in a laboratory, since this will depend both on the number of technical men who will use the stenographic services and on the nature of the laboratory work. If the laboratory carries out only research of a fundamental nature, the amount of clerical assistance needed will be relatively small. If, however, the work is in large part process development or sales development, considerable correspondence will be carried on between the laboratory and prospective customers or between the laboratory and plants. If the laboratory does considerable sales service work, this also will augment the number of clerical personnel needed. Thus it is not possible to predict the number of clerical workers needed for a given number of technical men. The authors of this chapter have found that in a laboratory employing approximately two hundred technical men, about eight typists are required for the sole purpose of typing research reports; about twenty-five secretarial aides are required for the use of group leaders, the central management, and others who occasionally require secretarial help; in addition, storeroom and shipping room, purchase orders, payroll accounts, routine correspondence, and the like require a total of about thirty-five additional employees. On the whole, about one clerical aide is required for every four technical men. It is believed, however, that this ratio is probably lower in many other laboratories where fewer reports are written.

For clerical work as with mechanical work, it is always advisable to employ a superior type of person. Here again, this is owing to the fact that in a laboratory most of the work is essentially nonrepetitive and requires clerical people who are able to adapt themselves to new routines and to make reasonable decisions in emergencies. For some types of clerical jobs, special training is very desirable. In addition to business-school training, a general college education, and more particularly training in the field in which the laboratory is working, will often make a secretary an invaluable part of the research organization.

Individual Assistants

Technical men need individual assistants to do operations ranging from the washing of laboratory glassware to the carrying out of routine well-developed procedures which require no technical training for their performance. The adequate number of such assistants in a laboratory is subject to wide variation. Generally speaking, most research men can profitably use one clever nontechnical person for these purposes. It is very doubtful if more than one can be usefully employed on the average by any one technical man, and sometimes a technical research worker is unable to direct the work of other employees even though he is fully qualified to carry out laboratory work himself. On the other hand, if assistants can be used to good advantage, a problem can be pushed to completion in a shorter time by their use and they should be available. On the whole, the average ratio of nontechnical to technical men will probably never be much greater than one to one.

A good nontechnical laboratory assistant is preferably an unusually intelligent high-school graduate who has good manual dexterity, a good ability to understand instructions, is reliable, and, ideally, is interested in doing laboratory work. Obviously the requirements vary with the kind of work the assistant is to do; if washing glassware is the only responsibility, such qualifications are not necessary.

People who have left college before completing their courses often do not make the best laboratory assistants. Generally, such people have left college for reasons that do not help in making them desirable employees in this line, although occasionally an exceptional one comes along. Science students in college sometimes make very satisfactory laboratory assistants during their vacation periods, but often it is not economical to hire temporary employees.

The chances for advancement for laboratory helpers are some-need for the protection of a guardian angel and the will of a champion to assist in bridging the swamp of hazards between the laboratory development and factory production.

The Gap Between Laboratory and Factory: Avoiding Dormancy and Circumventing the Graveyard

Preparation for the successful translation of the laboratory results into finished factory production should be started early in the research. In this connection the first problem is the choice of the proper subject. The executive on whom this duty falls has somewhat the same problem as the lawyer who desires a record of winning most of the legal cases he handles. It is a case of selecting out of the many available cases or problems those most likely to win. If this first choice is judiciously made, the path from the research laboratory to the factory will certainly be easier. Unfortunately the problem is not always so simple; but it should be emphasized that the proper selection of the subject matter will go far in helping to reduce the many obstacles confronting any research project.

Again, in preparing for the transfer to the factory, the laboratory should take stock and make certain that a thorough study has been made and that the process or product developed in the laboratory is a practical working solution of the problem. This means that the laboratory should have considered all phases of the problem including costs, applicability to factory conditions, etc. At the same time, much wisdom and discretion should be used to see that the research men do not spend so much time polishing up minor details that their work never finds an application.

After the laboratory has exerted every effort to lay the desired foundation for the transfer, there still exist many problems in effecting it. Dr. Kettering, retired head of research for General Motors Corporation, has said that the best way to sell a new device to his company is to sell it to a competitor first. In this statement, Dr. Kettering, in his inimitable way, is pointing out that there exists a problem in avoiding dormancy in bridging the gap between the laboratory and the factory and that a sales job or some other planned procedure is needed to circumvent that graveyard of many a good idea or development.

There are several reasons for the existence of this problem. First, there is the natural tendency for people and businesses to develop fixed habits or habit patterns. These are in the nature of stable equilibria in that there is a resistance to change and a strong tendency to return to the old until the new habit patterns are established. This resistance to change is caused in part by the hazards involved in any change. For example, there is the possibility that there might be an error in the laboratory findings or that they might be incomplete. Next is the frequent requirement for new equipment and the obsolescence of the present equipment. This is followed by production hazards incident to a change or new development. Finally, when the product is ready for sales, customer habits and practices must be given consideration and creative sales work must be done to change them. Even sales departments, although always desiring new and better products, are usually hesitant when presented with the product because it often means the application of more creative sales work as contrasted with competitive selling.

The research laboratory has the greatest knowledge concerning the results of its work and is sold on its findings. Hence, normally, it is necessary for the laboratory to take the initiative through its research or development head, or as a group, to inspire that same interest and acceptance of its findings in other departments of the company, and to sell them the product.

Too often the engineer is at a disadvantage at this point because he is accustomed to base his decisions on facts and figures. He lacks experience in the sales technique. The research man forgets that sales are made on impressions backed up by the necessary facts and figures rather than on the data and facts alone. This is especially true in the many instances where the men to be sold may not have the technical background to evaluate the data in terms of their specific interest.

Creative sales work to develop favorable impressions and interest must be done first if the gap between the laboratory and the factory is to be bridged effectively. If the head of the research or development division lacks the sales approach, someone in the organization should be developed for that purpose.

Timing is very important in any sales approach, and it is just as harmful for an overenthusiastic research director to create favorable impressions and too great interest in a new development before the laboratory is ready, as it is for the research head to have difficulty in creating the needed interest after the job is done.

A creative sales approach, properly timed and backed up by substantiating results and data, is essential in bridging the gap between the laboratory and the factory.

Although creative selling of the idea is probably needed, it is not desirable to use high-pressure techniques. Many so-called sales efforts by research people fail by being too aggressive, but in a clumsy sort of way. Hence, even though all research projects must be sold, it is unquestionably better to use the old mousetrap technique of trying to make the proposition so good that it sells itself than to hazard its future through overselling.

Need for Close Relations between Research and Production Men

Recognizing the lack of sales training in the average engineer, there is the possibility that closer relations between the research man and the production man might help overcome this situation and assist in translating research results into new products and factory procedures. It is just as difficult for the production man to see a test-tube result and visualize it in mass production as it is for a man not accustomed to engineering drawings to visualize production of the finished article from a perusal of the drawings.

The necessity for avoiding dormancy is recognized by all, but there are arguments for and against closer relations between the research man and production man as a means of accomplishing this. On the side in favor of close relations, there are:

1. Production knows what is being developed and can keep acquainted with the work being done. This helps because the development does not seem so new when it reaches the production planning stage. There is less resistance to an old idea than to a new one. Also, through previous thought the answers to many of the problems will have been worked out in the production man's mind before the necessity of answering these problems in actuality has arisen.
2. Through a knowledge of the development, the production men will have more confidence in the results, particularly because they will have had an insight into the numerous studies, tests and check tests which the laboratory has made in the course of the research.
3. A close relation between research and production men also assists the research man in selling the factory men simply because frequent opportunities to present his story will help counteract his lack of sales ability. The knowledge that the research man continues to be sold on the development is certain to create interest in those near him.
4. A close relationship also enables the production man to become acquainted with the research type of thinking and the research approach to a problem. This will assist him in his work and at the

same time assist in selling the factory because all men involved will then be thinking along parallel lines.

5. Conversely, a knowledge of production problems will not only give the research man new ideas on which to work, but will also show him some of the tests and studies he should make in order that a new development will be completely ready for production.

6. Sometimes the technical man with years of specialized training feels that he is superior to the higher operating supervisors and is inclined to be a bit scornful of their ideas. The successful operating man has climbed to his position of authority against severe competition and the openminded technical man will have little difficulty in finding considerable merit in the operating man's ideas if the relationship is close enough to permit a free exchange of ideas. A fair and full consideration of all suggestions made by the operating people will do much to assist in gaining acceptance of the research results by the operating people.

7. Actually there is a common interest between factory people and the laboratory researchers. If the project is successfully introduced into production, the research man profits because he has accomplished what he was employed to do, namely, to apply technical findings to new products or new processes. By the same token, the plant man profits if a new development that keeps his organization ahead of competition is added.

On the side against a close relationship between production and research men, there are:

1. A knowledge of production problems by research men may make them hesitant to make changes. Because of the production problems, they may delay releasing a worthy improvement of the product in the hope of finding a simpler solution, whereas the more complicated solution may be more economical than the cost of waiting for a simpler solution.

2. A close relationship between production and research tends to cause production men to bring problems to the research laboratory which they can and should solve themselves.

3. Because of this tendency, and a knowledge of the urgency which frequently accompanies a production problem, the research department is likely to gravitate toward being a service department for the plant and to place less emphasis on its research responsibilities. The possible seriousness of this, of course, depends on the type of men in the laboratory and the characteristics of its director.

4. Production men may tend to discourage the research men by overemphasizing factory difficulties.

Neither the favorable nor the unfavorable factors listed above are in order of importance, because the nature of the personnel in an organization influence the relative weight which should be given these factors. The correct balance between close and more distant research-production relationship has not been completely solved and depends on conditions, organization, and many of the intangibles existing in a specific plant. In view of this, the pilot plant has been found to be very useful and, in some businesses, almost necessary for bridging the gap and smoothing the way in the introduction of a new product. It not only supplies factual information and quantities for various investigations larger than can be produced in the laboratory, but it also adds a step in the transition from laboratory to production in which both the research and production men can have a hand. This applies equally well to the use of new processes or in the introduction of new products.

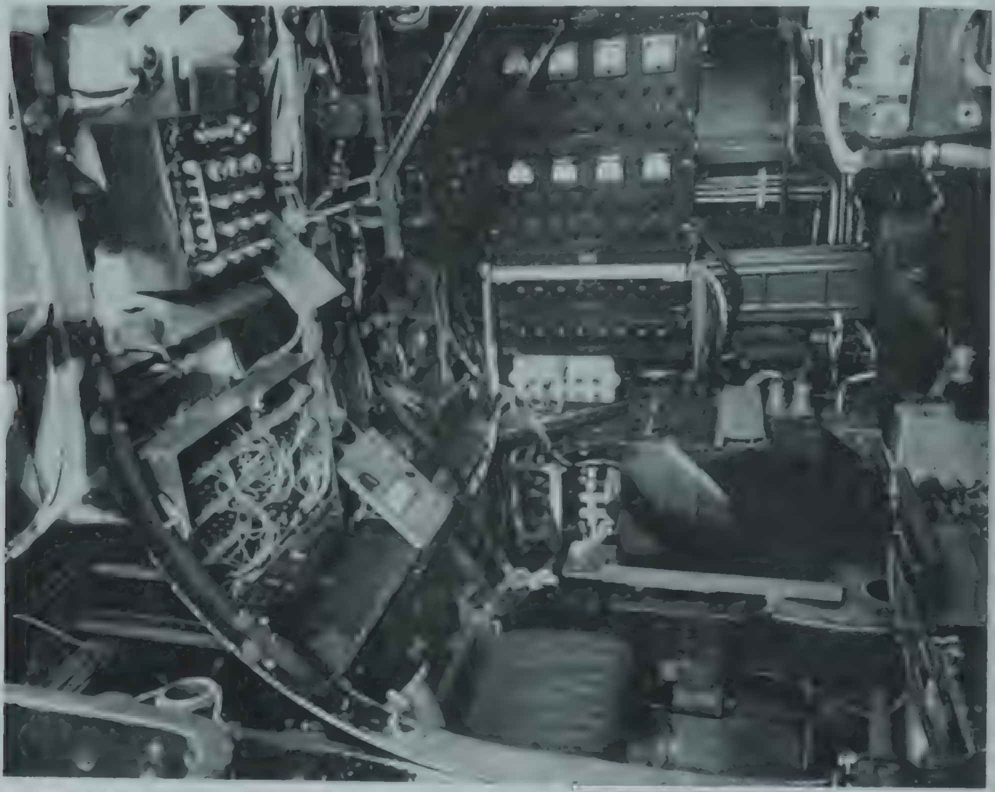

PHOTO. 38. Research takes to the air. A typical set of instruments inside a flight research airplane. (*Courtesy of the Cornell Aeronautical Laboratory.*)

The Role of the Laboratory Pilot Plant

By pilot plant operation, of course, is meant working out the process with equipment resembling mill or production equipment but smaller in size, or producing a larger quantity of product or material than can be obtained with regular laboratory facilities, but less than regular production quantities. The technique is widely used in the chemical industry and in metallurgical work. It should be recognized, however, that pilot plant work is expensive and should be resorted to only when the situation requires it. Sometimes it becomes desirable to use the entire plant as a sort of pilot plant—for example, a change may be made on one batch of material run through, or a small number of different products or designs may be run over the regular production line. The variation best suited for the particular development can be chosen after proper study.

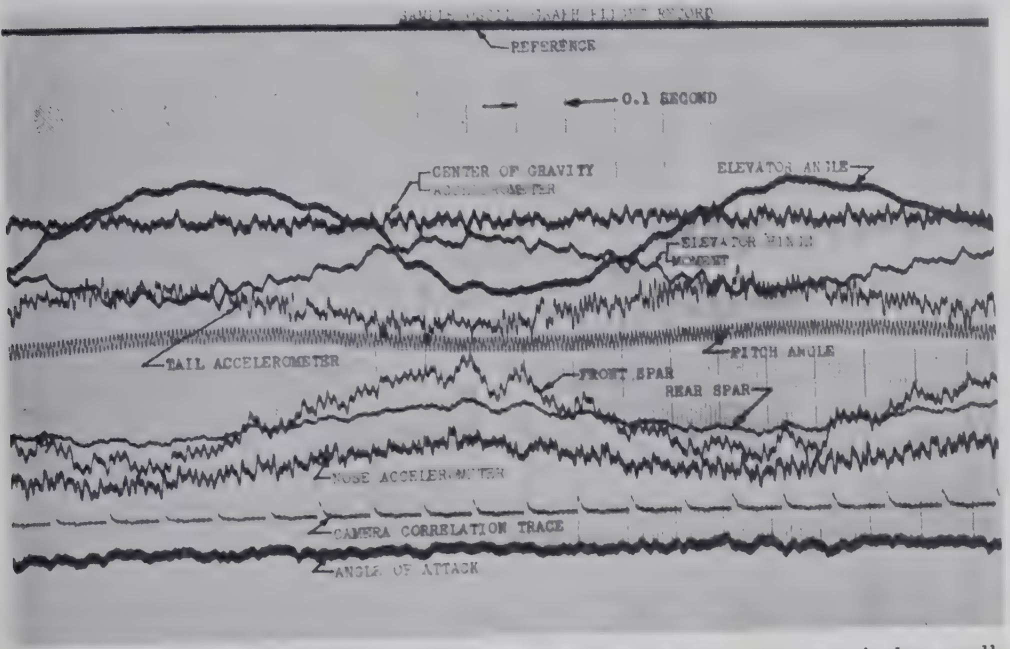

PHOTO. 39. Sample oscillograph flight record. The development of new airplanes calls for extensive and careful flight investigations. (*Courtesy of the Cornell Aeronautical Laboratory.*)

The pilot plant has evident technological advantages in preparing a research development for factory production and it serves as a check on the laboratory results on a partial-plant scale.

Through the use of production-type equipment, the problems encountered in the transition from laboratory apparatus to factory, structural materials are tested in model form prior to the major investment in plant facilities.

The pilot plant also becomes a medium for the study of changes necessitated by production and field test conditions. These changes can be made at less cost and more rapidly in the pilot plant than in regular production which is organized for large-scale operations. No disruption of related production items occurs while these studies are being made. Purity and yields can be studied and preliminary costs can be determined. In the case of durable goods and mass-production items, the opportunity to test tools, ease of assembly, materials, and operating characteristics is provided before the expense of large-scale production is incurred.

Production men can visualize the final plant better from the pilot plant operations than from observing the test-tube or laboratory process only. Through the actual operation of the pilot plant, they become familiar with the results and thus sell themselves on the desirability of the process or product. The pilot plant is thus an effective aid, not only in obtaining experience on a small-plant scale, but in developing a common interest and co-operation between the laboratory and factory personnel.

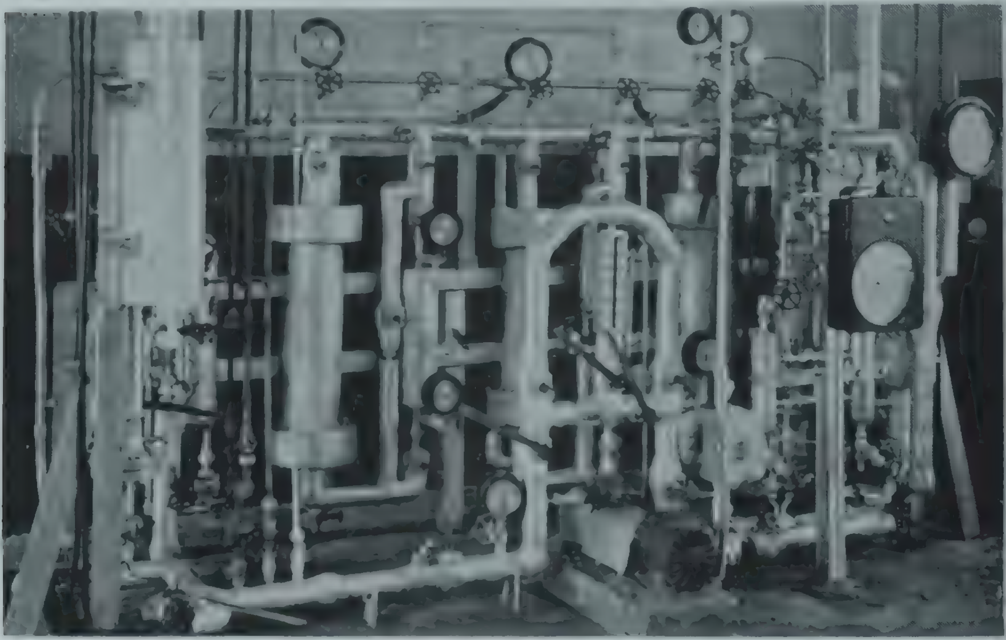

PHOTO. 40. Pilot plant unit for copolymerization of olefins. (*Courtesy of the Humble Oil & Refining Company.*)

Any new process or product requires certain laboratory and factory controls and test procedures to assure consistent production. These can seldom be worked out in the laboratory, whereas the pilot plant is an ideal medium for this purpose. Through this procedure, the factory men learn that the product or process is capable of consistent production under factory conditions. At the same time, the operation of the pilot plant affords an opportunity to train a nucleus of men for the operation of the production process at a later date.

Lastly, and very important, the pilot plant is a source of new products or samples which can be used in studying the market, obtaining field experience, and in influencing or selling prospective customers. This is particularly true in the chemical field and in fields where materials are the end product. In some cases this study may show that the demand is limited and that the pilot plant can fill the demand. In other cases the pilot plant helps determine the various types of demand and serves as a basis for determining the size of the final production unit. Thus the pilot plant gives a check not only on the methods to be used in the production unit, but also on the probable size of this unit before the more costly procedure of establishing a major plant operation is undertaken.

PHOTO. 41. Control board of a fluid catalyst cracking pilot plant unit. *(Courtesy of the Humble Oil & Refining Company.)*

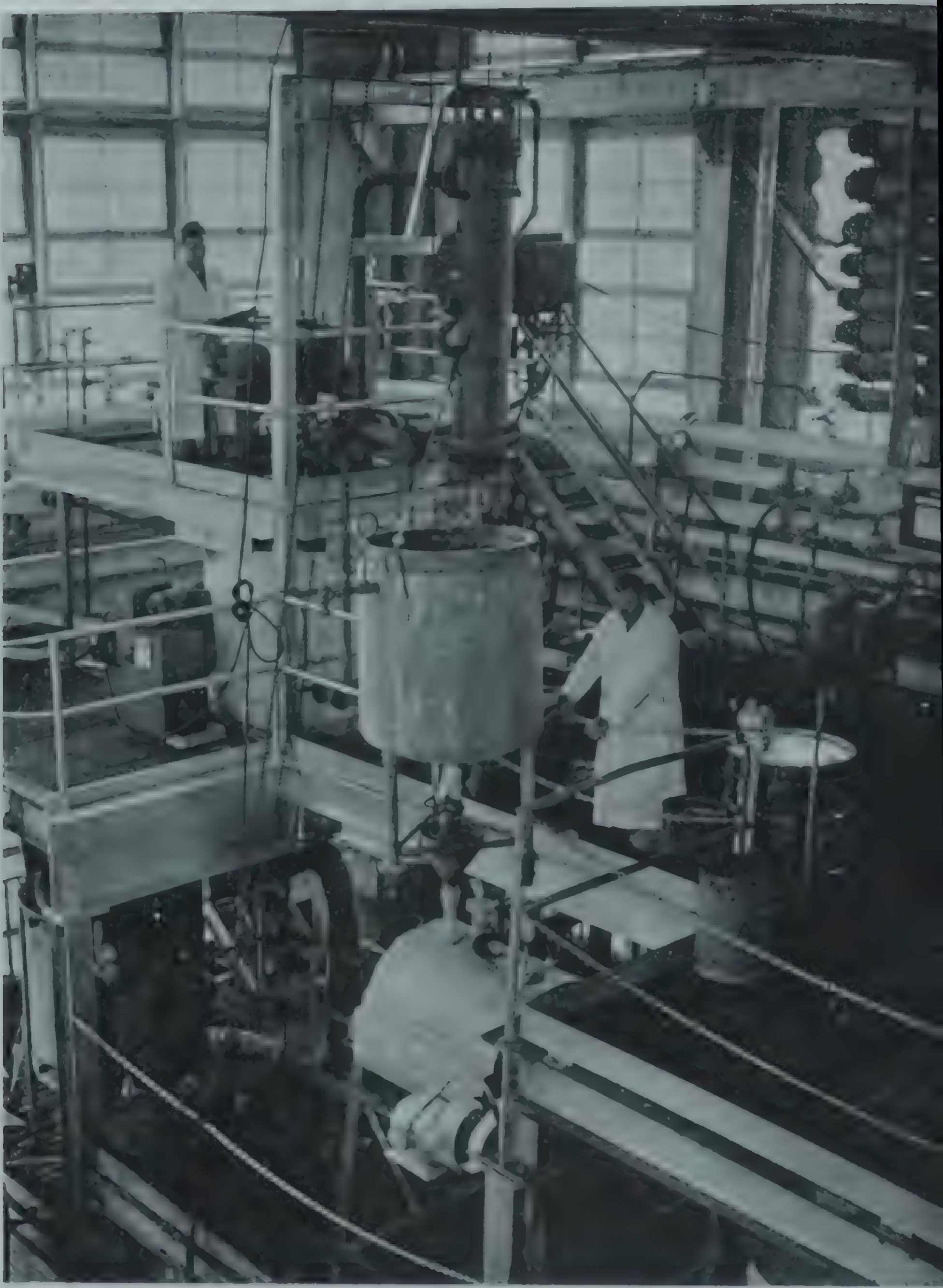

PHOTO. 42. Pilot scale operations in a chemical plant. (*Courtesy of Heyden Chemic Corporation.*)

The relationship between the original research expenditure ar the cost of converting a laboratory product into a marketable ite varies greatly. For example, a durable goods product selling fo about the price of an automobile might cost a million dollars to develop and several millions through the pilot plant stage to the point where a profit is being made. Again, a process improvement might cost only a relatively small sum to develop and still warrant scrapping large sums in the form of capital investment because of production savings. Then there is the specialty chemical, such as a drug in great demand, which may require a considerable expenditure for research and still show a definite profit over previous manufacturing costs even in the pilot plant stages. Similar examples can be found in the development and production of specialty durable goods as contrasted with mass-production products.

The pilot plant is frequently set up as a part of the laboratory operation on the theory that the research laboratory will have a greater incentive to make the product or process a success, since it is their brain child. Also, changes in the product or process may be introduced with greater speed and facility when handled by the laboratory or engineering department in contrast to following a fixed factory procedure based on the needs of large-scale production. When the pilot plant is under laboratory jurisdiction, there is some question whether production gets the full knowledge and experience necessary to carry on when responsibilities are transferred at a later date. The advantages probably outweigh this possible disadvantage, particularly in the case of entirely new products, or products requiring major changes. In mass-production industries, in contrast to the chemical industry, the steps preliminary to the introduction of new models may well be undertaken by the factory. The pilot plant operation in this case takes the form of building a number of samples according to specifications before starting the production lines. This provides an opportunity to check the time and space requirements of the assembly operations and to work out improvements to facilitate putting parts together.

Since the pilot plant has for one of its primary functions the transition from laboratory to production, as many of the operations should be assigned to production as is feasible. For example, even though the pilot plant organization is a part of the laboratory, the design and layout should in general be done by production men to the laboratory's requirements. The erection should again be the responsibility of the production men working with the laboratory and to the laboratory's specifications. Changes needed as a result of experience gained in the operation of the pilot plant should be carried out by the production organization, especially if more than minor in nature. Even if there are cases where the pilot plant is operated entirely by the laboratory group, the production men, who will later assume responsibility, should have access to the operation.

Transferring the Men with the Product

Knowledge and experience can only be measured and used in the form of manpower. The research man becomes the first expert on the process or product which he develops. This knowledge must be transmitted to others in order that the product or process may be successful. This would indicate that the research man should follow his development work through to the end result.

Against this, the research man frequently has certain characteristics which make him more valuable to his company, and consequently to himself, on other research problems than on following a particular product or process through to its final conclusion.

The research man is always working for future results, whereas the production man's job is to get the most from the present. This being the case, the research man always looks for and sees changes and experiments which can be made with the idea of creating further improvements. If frequent changes are made, production suffers. Hence, changes should be held for periodic treatment.

In general, the research man does not have the type of executive ability or experience needed for production operations. Against this, he has developed the product or process and holds the prime interest as well as the major knowledge in it. From this, it is seen that much depends on the man as well as the process or product. In some cases it might be wise to transfer the research man with the product as it moves from laboratory to pilot plant, to production and to sales, stopping him at that point where his capabilities fit him best. In other cases, the research man or an assistant might move with the product and be returned to the laboratory after the product has been proved in the pilot plant. This experience becomes a part of his training for higher responsibilities in the laboratory. In every case, however, it seems that the research man should be closely associated with the product until a nucleus of men with production knowledge has been trained in the pilot plant. For the pilot plant or initial production stage, men with production experience and executive ability should be used under at least staff supervision of the research department until it is decided to build a production setup, at which time these men should be transferred with the product and the research man returned to another problem, retaining what might be called a consulting status.

In every case, if men are transferred to the factory, adequate provisions must be made to replace them with equally good men or the laboratory will soon lack the spark needed to keep going and will lapse into mediocrity. It has been said that more than one company has had to go out of business because it lost its laboratory force to production and, hence, lost the new developments necessary to keep the company in a competitive position. Sometimes the reverse condition appears and excellent men are found in production who can be transferred to the laboratory staff.

So many considerations influence the decisions reached that the above statement can only be considered as a generalization to be modified by circumstances. In principle, the pilot plant technique, where employed, creates an exceptional opportunity for closing the gap between the laboratory and the factory as well as for gaining experience, materials to work with, and determining needed facts. It exemplifies the wisdom of Dr. Baekeland's admonition: "Commit your blunders on a small scale and make your profits on a large scale."

CHAPTER XX

By-Products of Research

The accomplishments of industrial research are generally thoug of in terms of new products and processes. Definitions of industria research invariably refer to new products, but it is quite apparen that there can be no sharp differentiation between the new end products and the by-products of industrial research. The end point fo one line of endeavor becomes the starting point for another. Th by-product becomes the objective. In trying to evaluate new business prospects for a client one well-known research bureau, as th result of a survey, stated: "In looking over all of these new developments we can characterize them as amazing, and many times throughout this survey we have felt like the proverbial country 'hick' wh gapes at the big city when he comes to town." This observation wa partly the result of the modern high rate of scientific change an partly owing to the fact that industry has not yet had time fully t translate war developments into their commercial by-products an uses. The release and control of nuclear energy is first on the list with its peacetime contribution as a source of heat energy, radioactive fission products, neutrons at high energy levels, and radiatio of the X-ray type. The chain-reacting pile has started a vast new chain of events of importance to science and industry. Since th uranium pile cannot make the same variety of radioisotopes as th cyclotron there is renewed interest in the building of new and mor powerful "atom smashers," and the knowledge of nuclear physics and chemistry continues to expand at an enormous rate.

Another important outgrowth of the research on the pile is the development of highly fluorinated stable and inert compounds suitable for use as coolants. These results, added to the knowledge o

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This chapter by W. R. Hainsworth, Vice President in Charge of Engineering an **Research, and R. S. Taylor, Chief Engineer, Servel, Inc.**

how to handle and produce the highly corrosive fluorine compounds safely in large quantities which are needed in the manufacturing processes, made their contribution to the plastic industry by facilitating the production of a new plastic, "Teflon," a highly fluorinated plastic material having interesting and useful properties.

Similarly, knowledge of value to the refrigeration industry is made available to improve the commonly used fluorinated refrigerants and even create new ones. As each new chemical or process is made available, it is adapted to a great variety of end products by the ingenuity of the research engineers in laboratories having entirely different fields of interest. As the story goes, a Dow chemical customer returned a gallon of dry-cleaning fluid because it had solidified. In seeking the cause, a new plastic material made from vinylidene chloride was created and called "Saran." Pipes made from Saran carry corrosive liquids without damage and do not burst when water in them freezes. Among other things, it is used for the production of a material which resembles leather. Another company starting with the same base material directed its research toward the development of a new window screen. There seems to be no limit to the ingenuity of a group of industrial researchers in creating new end products when given a new material to work with. The base material itself was undoubtedly the primary objective for a companion group of industrial research workers.

Although it is difficult to unscramble the direct and indirect results of research as it affects products, there are many benefits of an intangible nature which do not affect the product but which are nevertheless very important. Dr. Jewett, in speaking of the value of research, said:

> I am, however, not at all sure that these direct results are the greatest benefits which have accrued to the industries from the introduction of industrial research over a long period of time. I rather surmise that if we had the means of measuring them, we would find the indirect benefits were of even greater value. These indirect benefits have been largely the result of the gradual change of point of view and methods of attack which have flowed out of the industrial research laboratory to all parts of the organization.

They cover a wide range of subjects, including public relations, advertising and sales aids, technical services and leads, and even products for which uses have not yet been found.

Company Prestige as an Aid in Maintaining Good Public Relations

Industrial management now recognizes the value of research in providing the opportunity to enhance company prestige and create good public relations.

The public in relation to the company comprises a number of different groups, each having a special interest in company affairs and some having an interest from more than one point of view. The stockholder, the employee, the user or consumer of company products, and the prospective customer, all have a direct interest in company prestige.

Maurice Holland, in commenting on the stockholder's point of view, points out that more than three hundred out of seven hundred recent annual reports of industrial manufacturing companies, whose securities are traded on the New York Stock Exchange, made some reference to the research activities of the company. The stockholder and those interested in the company securities are particularly concerned with the safety of their capital investment, dividends, the position of the company within the industry, and its future prospects. Research activity is being recognized more and more by this group as an asset which has a direct bearing on the future of the company. The practice of publishing information on research expense is leading to a new investor's ratio for company evaluation, namely, the percentage of sales income devoted to research, which indicates the extent to which management feels it can profit from research. This represents a considerable change from the experiences in the early days of research in industry which caused the late Arthur D. Little's remark, "Every chemist will admit he needs a banker, but not every banker will admit he needs a chemist." The statement by a duPont official that "in 1942 nearly half of duPont's gross sales—46 per cent to be exact—consisted of products that either did not exist in 1928 or were not then manufactured in large commercial quantities" is representative of the importance of research to the stockholder. In another field, a consumer-goods producer states that 25 per cent of 1944 sales consisted of products developed in the company's laboratories in the preceding ten years.

The employee has a direct interest in the security of his job and the company's ability to equal or better opportunities which he may find elsewhere. Aside from these materialistic matters, the employee also feels ordinary human pride in the prestige of his corporate family. If he does not have this feeling he may still be a good worker, but in a true sense he is not a good employee. If he feels that his company is in a leading position as proved by practical research results, along with the recognized advantages of high productive efficiency in the factory, aggressive sales organization, and good personnel relations, he becomes a booster and develops a loyalty which adds materially to company prestige and stability. These considerations are not merely idealistic; they have been proved to be an important factor in employee relations. Those companies which make a practice of having an occasional engineering and research open house day, and who keeps employees informed on engineering developments, are well aware of the resulting interest and good will.

The consumer and sales prospects for company products constitute the most important part of the public in relation to the future of the company. If this group, by ordinary every day conversations, or by comparing notes in the office, or any other means of communication, is convinced that the company products are outstanding in comparison with competitive products, its full quota of sales is bound to be realized. It may be trite to make such a statement, but the fact remains that the first, and one of the most important, steps in attaining this enviable position as a favorite topic in private conversations is to provide a properly engineered product as it emerges from the laboratory. Basically the product must be right in design or composition as it leaves the engineering or research laboratory. With this foundation the factory, then sales promotion and advertising, set the stage for selling the product. When the public knows by experience that the product is right, an environment favorable to dividends is created and a large measure of good will is bound to result as a by-product.

Advertising Copy

The effectiveness of both institutional and product advertising is recognized by management as being continuously influenced by technological developments. Research results are an important tool in the hands of management, inasmuch as they contribute to the acceptance of sales promotional material and advertising copy. Whether or not the story is couched in chemical symbols and technical terms in trade journals, or designed to appeal to the imagination of the public as a whole, the objective is to inform people that something new or better is, or will be, available to them.

One of the primary functions of advertising is to reduce sales resistance, or expressed positively, to increase the desire to buy. It is a confidence builder, and because of this it is far better to base advertising copy on facts rather than on imagination. The modern trend is decidedly in the direction of the greater use of facts, and facts stem from the research laboratory.

The methods of presenting the facts to the public vary greatly. In the advent of new products or processes, or new research facilities which are of general interest, the announcement may first appear as news items. The plans and facilities of the General Motors Technical Center, dedicated to the creation of better automobiles, have news value because of the center's magnitude and objectives. The Standard Oil of New York Research Forum, with leaders of science and industry participating in the discussion of current scientific events and with hints of things to come, is of sufficient general interest to make good reading in the nation's newspapers. Spectacular accomplishments such as new speed records for jet-propelled planes, or the proposal that the limits of television reception be greatly extended by using planes for broadcasting stations, have a free publicity value for the sponsoring organization.

Obviously, only a very small fraction of the accomplishments of industrial research reaches the newspapers as news. Advertising paid for by the company is much more effective as a builder of confidence in the products or service sold by the company.

The civilized world is science-minded. Any product on the market today, if worth while, will have a history of industrial research accomplishment on which the finest kind of factual advertising copy may be written. The public is now more concerned with the technical excellence of a product than with brilliant pseudo-literary writing based on generalities (once described as "yodeling nonsensical ballyhoo") about it.

Progressive companies continually seek ways and means to capitalize on laboratory research in improving their sales message—all directed toward improving the market for their products and reducing the cost of distribution. The public may be impressed by advertising company research facilities. Some products may be related to other developments having a popular appeal. For example, the

Minneapolis-Honeywell Regulator Company effectively ties in its laboratory work on household and industrial electronic controls with the automatic pilot for airplanes. The copy may be more direct, such as General Electric's "How you profit from this discovery," which leads to a description of a new electric furnace for brazing. The appeal may be patriotic, as exemplified by General Motors' "Who serves progress serves America." The B. F. Goodrich Company has for many years leaned heavily on its research and development capacity in its advertising campaigns. In this case, a human-interest catch-phrase, used to catch the eye, is followed by a description of the accomplishment. The phrase, "It's a pipe," leads one on to read about a new rubber sealing compound for sewer pipes.

Many exhibits and displays, and even consumer research surveys, make use of advertising copy based on technical accomplishments. These range all the way from the elaborate "House of Magic" and "Motor Caravan" to the modest product questionnaires and surveys which serve the dual purpose of building company prestige and of bringing information to the development department.

In general, advertising copy has now attained a high plane of reliability in representing the company and its products to the public. This was not alway so, and in the early days before the so-called consumer movement got under way, flagrant exaggerations and misrepresentations were used. Even today there are a few remnants of this practice in existence, particularly in those fields where personal usage becomes a factor. Consumer relations are recognized in the advertising business, and careful studies are being made of the consumer movement in terms of what the consumer talks about at group meetings; the demand for more real information in advertising and selling, and adequate protection; and, finally, for clarification of advertising problems in public relations. These all point toward a future of closer co-operation between the advertising and technical man.

Opportunity for the Company to Enter New Fields

It has long been recognized that one of the important functions of industrial research is to seek new products or processes or to develop new methods which will place the company in a favorable position to develop new business as differentiated from expansion of the business in which the company is engaged. This objective o diversification of the company's business may have formal and direc recognition in the form of appropriations to cover the study of certain chemicals, or some new appliance or piece of equipment. A large part of industrial progress is based on this type of organized search, but occasionally there are by-products in the form of new and unexpected things which may be brought to light in the course of the work on specific projects. This may be interpreted as applying actual materials for which there are no known uses, or for which new uses may be found; or the by-product may be in the nature of a new method which may be used to improve known services or create new ones.

In the early days, that branch of the fermentation industry which was founded to make acetone for powder manufacture, soon discovered that the by-product, butanol, was more valuable because of its usefulness in lacquers. Even the long-distance telephone, according to Michael Pupin, was an outgrowth of the effort to improve telegraph systems by using harmonics. In the rubber industry the early acid process occasionally caused sponginess in products, especially if they contained acid reclaimed rubber. In an effort to correct this fault by improving the acid process, a new alkali process was developed which eliminated the trouble and reduced the cost of many rubber products as much as 50 per cent.

In later years numerous examples continued to occur. Research chemists for the Goodrich Rubber Company were looking for a substitute for shellac in the making of phonograph records when one of the experimenters noticed that one of the substances was extremely difficult to remove from his fingers at quitting time. It was found that by using it as a cement for rubber and steel, and combined with a new method of vulcanization, the rubber could be attached to the steel with an adhesion exceeding five hundred pounds per square inch. Rubber-lined tank cars for acid transportation, rubber-lined pickling tanks, and even rubber-covered metal chutes for handling rock, are the indirect by-products of a photograph record research.

Technical Services: A Selling Aid for the Sales Department

A considerable part of the time in most industrial research laboratories is spent on the problems involved in correcting the faults of existing apparatus, the improvement of processes of manufacture, esting, and a multitude of activities which may be classed as technical services. Work of this nature constitutes a bridge between the aboratory and the field. Even the negative results obtained in the laboratory give knowledge which can frequently be used in the field. The laboratory is one of the important sources of information, as it serves as a practical guide in the development of new products or in the control of industrial processes and applications. Here again the degree to which technical services are developed depends largely on the industry. They are highly organized where there are complex machinery and industrial equipment, and are of considerable importance in the durable-goods industry, sale of manufactured materials, and in connection with some chemical or industrial processes.

In each case a technical service department may be of appreciable value to the company as a selling aid, as well as a source of information for the laboratories. Even though the service may be in the nature of information supplied to meet an emergency, trouble shooting, or correcting products which do not come up to customer expectations, it can be used for sales capital. Unless such conditions are attended to at once, the sales department will shortly encounter new hurdles which are promptly elevated by competitive salesmen. If effective service is rendered, the salesman's story is strengthened by confidence in his company's ability to overcome unexpected difficulties. In other cases the customer is sufficiently experienced to realize that unknown difficulties and problems are bound to occur; an experienced and well-trained technical staff is accepted as a major asset in his consideration of the product.

Many laboratories render technical services to the field through their own staff as an aid to the field sales or service men. The research and development laboratory develops specialists on the product. A particular field problem may require the assistance of one of the specialists for the most speedy solution. Through this type of service the laboratory itself can be used as a selling aid. This applies whether the trouble is in a complex mechanical or electrical device, or whether the results or yields from a chemical reaction are not as expected. It is true that this type of aid may be considered as a sales support rather than an aid. Satisfied customers, however, are industry's best salesmen, and from the point of view of satisfied customers, a very valuable sales aid results from this type of service.

There are also the more direct sales aids which can be and are rendered by the research and development groups. It is one function of the laboratory to furnish the sales groups with information concerning properties, performance, and possible uses of the product. The sales group bases its literature, advertisements, and sales presentations on this information.

Lastly, the technical group frequently acts as an adjunct to sales by participating in discussions with the customers' technical men. This is particularly desirable in marginal cases where a product may seem to be correct for the planned usage, but has never been tried in this specific manner. Also, the customer frequently desires some slight modification of the product for his specific use. An expert opinion on the feasibility of this is a technical aid to be given the sales group. In rendering aids of this sort, the technical man also becomes better acquainted with field conditions, and this serves to guide him in planning his work to be of greatest value to the sales group.

Some products are sold without the customer's being particularly concerned about the manner in which they accomplish the result. For example, the complex electrical circuits employed in electronic controls are of no particular interest to the head of the process department specifying the control. He is interested mainly in reliability, performance, and cost. Closer to home, the housewife is not concerned with the principles of operation of her automatic refrigerator or washing machine. She thinks of the kind of job it does, its durability, and cost of operation. Nevertheless, both the factory man and the housewife have a natural curiosity about the product they expect to use and a layman's explanation, based on technical information, supplied by the technical service groups, may be used effectively by the sales departments in making the sale. After this, the sales service department of the company is expected to take care of day-by-day service requirements until such time as unusual circumstances are encountered which again justify calling for the more basic information which the technical service group is capable of supplying.

There must be close relationship and co-operation between the technical service and sales organization. In general, the sales department requests aid from the technical man and makes the arrangements for field and customer contacts. If the technical aid is required in connection with product or process complaints, it may be advisable to have representatives of the sales department present during meetings with the customer. Obviously, the information supplied by the technical and sales groups must not be in conflict.

In summary, the research and development groups can render valuable technical aid to the sales groups, both through information and advice, and also through actual services in the field. This latter phase of their aid must be used with discretion and only where it is of definite value.

CHAPTER XXI

Evaluating the Results of Research

That the results of scientific research are valuable to mankind probably no one will deny. The broad view readily encompasses the benefits in the way of improved health and greater convenience in every day living.

It is perhaps a reasonable conclusion that all industrial research is directed ultimately toward the gratification of some human desire for:

Security, either national or individual.
Shelter.
Clothing and adornment.
Food.
Health and welfare.
Transportation.
Communication.
Amusement.

In some cases it may not be obvious that the research effort is related to the fulfillment of a human desire, but it is only a matter of the number of steps which separate the result of the specific industrial research effort from the highly personal need. Examples are all around us, and one is picked at random: The invention of a new catalyst for the oxidation of ammonia may seem a long way from one of the human interests listed above. This development, however, relates to an improvement in the process for making nitric acid, which is needed to nitrate glycerine, to give a dynamite to mine copper to make wire for a dynamo that generates current for the convenient lighting of the home, and thus winds up with the fulfillment of a human need.

Thus, ultimately the value of any industrial research is to be

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This chapter by Fred Olsen, Director of Research, Western Cartridge Co., Division of Olin Industries, Inc.

measured in terms of added human satisfaction, although this is usually too indefinite and too impractical to be used as a measure of the degree of success of the industrial research effort.

At times, it is possible to say that research has been valuable without being able to translate the value into dollars. For example, the fixation of atmospheric nitrogen to give ammonia which can then be oxidized to nitric acid, had a tremendous effect upon national security, because it is quite obvious that the enormous supply of explosives produced in the United States during World War II could not have been possible if we had been obliged to rely upon imports of Chilean nitrate. Many people hope that the value of these ammonia plants will be even greater when measured in terms of protection against starvation of millions of people in stricken nations, where fertilizers made from this ammonia can increase their food crops.

There are many outstanding examples of definite financial successes which are based upon research. The improvements in the cracking of oil have not only increased greatly the yield of gasoline, but also added to the over-all wealth of the nation by conserving our oil supply. The development of hybrid corn has increased the dollar return from much of our agricultural labor. Rayon researches have made many dollars because the new fiber has contributed to the clothing of so many people. Sulfa drugs and penicillin are earning profit for the manufacturers and at the same time are increasing the health of the community. The inventions of the incandescent lamp, the automobile, and the radio have resulted in a big dollar return and have been the basis of several large industries employing literally many millions of men.

A board of directors, however, does not approve a research budget on the basis of the pleasure that some ultimate consumer is going to experience, but on the profit which is more immediately to be received. If the research effort does not increase the financial returns to the company, it will not be regarded as successful.

The immediate concern is, therefore, to see if it is feasible to determine the return for each dollar expended on resarch.

Why does industry want to get this dollars-and-cents measure of the success of research? Because management must have an objective basis for evaluating research, just as it can evaluate the improved production of the factory, the performance of the sales department, or the judgment of the credit department.

It is not enough for a research director to say, "Our company was built upon the results of research, and our management does not have to be shown each year the dollars-and-cents return on its research expenditures. They know that research pays." This may be quite true, but it is only qualitative.

In 1908, when General Motors was incorporated, no man living could have foreseen that a single private enterprise within a period of about thirty years could create wealth in the form of corporation assets which would be more than the total national debt at that date. Such, however, was the case with General Motors Corporation, according to a recent popular writer, and this growth was based upon the sound application of industrial research. During this same period, the value of products sold by that corporation increased from about $4,000 per man-year in 1911 to $8,000 per man-year in 1941.

Whenever consideration is being given to the dependence of industry upon research, it should always be remembered that a successful business is also dependent upon sound management, upon a progressive sales policy, and upon a number of other contributing factors, such as increased factory efficiency and effective advertising. What management would like to know more specifically is the role played by research in building up this increased dollar strength of the corporation.

Perhaps almost all companies regard research as a form of insurance against obsolescence and the loss of business to new technologies in the hands of competitive interests. For example, wood distillation companies were seriously threatened in the 1920's when synthetic methanol was produced more cheaply than wood alcohol could be recovered, and when acetone produced by fermentation cut the price of acetone recovered from their distillation products.

Measures of the Value of Research

Surely it is desirable to show to what degree the results of 1946 research effort were better than those of 1945, and how much better than either are the results of the 1947 developments.

Certainly the director of research is in a much stronger and more forthright position, if he can use some acceptable yardsticks to measure the progress of his organization.

There are three main fields in which industrial research is done profitably:

1. The lowering of costs of production.
2. The improvement of quality of products.
3. The development of new products.

The lowering of manufacturing cost is one thing which makes a direct appeal to management, because the savings can be readily determined. There may be less raw material used, or a greater yield secured, or less labor involved. Merely to state that a 10 per cent greater yield is now obtained, or that 15 per cent less labor is now used, is not, however, the whole story needed by the board of directors. It is more convincing to show the difference between the cost of the product as now made and the cost before the improved process was introduced.

In many companies it is considered essential to determine those savings in quite a formal manner. When the development of the improved process has been worked out to the satisfaction of the research division, the new process is described in detail and with full documentation. All specifications of materials involved, all methods of testing, and the results of applying these methods of testing are given, after being attested by an independent inspection division. This book of procedure is formally offered to the works manager, with the understanding that there are only two things he can do with it. Either he accepts it for trial manufacture, or he must reject it for reasons stated. In other words, the report cannot lie around without yes or no action being taken on it.

Some members of top management—that is, an executive of the company at a higher level of authority than either the works manager or the research director—is advised of the time of acceptance of this improved process by the works manager. The reason for this is that it is beyond the jurisdiction of the research director to assume responsibility for actually putting this improved process into practice. A means must be provided so that accepted improved procedures do not lie unused. A good method of accomplishing this end is to present the research division's estimate of anticipated savings of materials, labor, etc., compared with the base-line conditions, prevailing before the new process is introduced, as established by the auditing department. It is then management's direct concern to see that this potential saving is actually earned. Of course, the capital investment needed to secure this saving must be shown in order that the return on the investment can be clearly recognized.

When this improved process is put into operation, the cost accounting department reports, preferably monthly, or at least quarterly, just what the saving has been. This saving is calculated only on the recorded actual shipments of salable product made by this improved process.

A specific example of the way in which manufacturing savings are recorded is given at the end of this chapter.

These savings are recorded quarterly *for one year only* as a measure or index of the return on the research effort expended on the process.

Of course, this return is not actually given to the research division, nor is it even stated as a credit to that division. Any claim for credit usually has repercussions from the factory which produced the articles made by the process, or from the sales division which sold them, both of which may feel that they have contributed as much as, or perhaps more than, the research division.

Recording these savings, however, for only one year has had the effect of appearing so modest a procedure that we have invariably had the full co-operation of the factory and sales divisions. Since the savings are usually recurring for several years, both factory and sales are apt to feel that they can show improved returns for *their* divisions even if the first year's savings were regarded as a credit to the research division.

With a new product, the case is more complicated. Some companies record the accumulated profits earned by the new product throughout its life as a measure of the research effort. But very few products emerge fully matured like Pallas Athene from the brow of Zeus. It would be misleading to regard the accumulated earnings of tungsten filament bulbs as a return on the research investment originally spent in the drawing of tungsten wire. Enormous sums have been spent since then in developing the lamp, and there is probably little value in stating the total earnings in terms of the total research and development expense over a long period of years. The concern of the research director is of a much more contemporary character. He wants to be able to justify in a sound manner the expenditures proposed in the budget being offered to the board, in terms of the estimated earnings anticipated from this research effort, and supported by the past performance of earnings arising from previously approved research budgets.

If an attempt is made to claim the total earnings of a new product as the measure of the initial effort, conflict will soon be encountered when subsequent research budgets contain items for the "improvement" of that product. Some other plan will obviously be needed to evaluate the results of the research effort on the improvement of the product.

Evaluation at The Western Cartridge Company

One method has been found quite helpful in measuring the return from research on new products. This is to record a part of the profit earned for a period of years. In the Western Cartridge Company, Division of Olin Industries, Inc., the practice is to consider 3 per cent of the gross sales of the *new* product for a period of three years, as a fair measure of the value of the research. This is, of course, provided that the profit amounts to at least 3 per cent of the gross sales; if less than 3 per cent, then only the actual profit is recorded.

For *improvements* in products there is recorded 3 per cent of gross sales of that improved product *for only one year.*

The selection of the figure of 3 per cent of the gross sales as a measure of the value of the new or improved product is admittedly arbitrary. Whether or not the figure is 3 per cent, or some other figure, is perhaps unimportant. The main thing is to secure the decision from management that some ratio be adopted, and that these numbers be used each year to see whether performance is improving or deteriorating.

The percentage will probably vary from company to company and may be changed as experience shows some other ratio to allow a figure to be calculated which seems to represent more closely the actual return.

The figure of 3 per cent is being adopted in this discussion for another reason: namely, the recognition by many companies that this is a desirable average ratio of research expenditure to sales.

In this there is perhaps the implication that if 3 per cent of gross sales is an appropriate figure to be expended on research and development designed to add new products or refresh existing ones, it is likewise a figure which can be used to measure the value of new products or of those items whose quality improvement has made them more salable or more able to resist aggressive competition and maintain sales volume.

Likewise the selection of three years for new products and one year for improved products as the time over which the index of return will be recorded is arbitrary; but if longer periods were used and repeated improvements were made, it is possible that a pyramiding of these numbers might occur, which would distort rather than represent the measure of value of the increased quality.

It must be clearly indicated that these calculated quantities are not a "credit" applied against the research division expense, nor does the research division share in this amount recorded as an earning attributable to research. As a matter of fact, it is probably best to avoid all talk of "credit" to the research division, and to use these numbers as making up an index, which in the Western Cartridge Company, Division of Olin Industries, Inc., is actually called an "Index of Return."

This Index of Return is the sum of three numbers:

1. The recorded savings for one year on process improvement.
2. 3 per cent of the gross sales of new products for three years.
3. 3 per cent of the gross sales of improved products for one year.

This Index is a *number*, and care is taken to leave off the dollar sign. It is recognized as being a measure of dollars earned but is *not* the actual sum realized. Actually, this Index is regarded as a very conservative measure of the dollars earned. It is hoped that as more years of experience accumulate, it will be possible to show that the numbers in the Index of Return should be multiplied by some factor greater than unity to give the dollars earned.

The Index, compiled every quarter from figures supplied by the auditor, serves as a yardstick by which the activity of the research division can be compared against previous efforts.

It will be realized that the third item in the Index of Return, comprising a measure of the value of an improved product, is one which has always been particularly troublesome to evaluate. It is probable that in many companies debate has often occurred as to the relative responsibility of the research, operating, sales, advertising, and other departments, for the increase or maintenance of the volume of sales of a product. It is perhaps impossible to determine whether an improvement in quality of a product is more responsible, or less, for increased volume of sales, than the campaign launched by the sales department, or the new techniques of the advertising department.

Once again it is perhaps more desirable to refrain from claiming "credit," and to adopt a conservative position of recording as one item of an Index of Return the fact that an improved product has been developed. Also, the formal acceptance of this improvement in product by the works manager, who has to make it, and by the sales manager, who has to sell it, is necessary.

The chart illustrated below shows the "Index of Return" by quarters for the past two years for the Western Cartridge Company, Division of Olin Industries, Inc. Actually the Index of Return was started in 1944, but experience had not shown how to apply the proper accounting methods, and the figures were not therefore comparable with the Index as it is now calculated and as shown in this chart. Furthermore, no returns were calculated on any researches performed prior to one year before the date of adopting the Index.

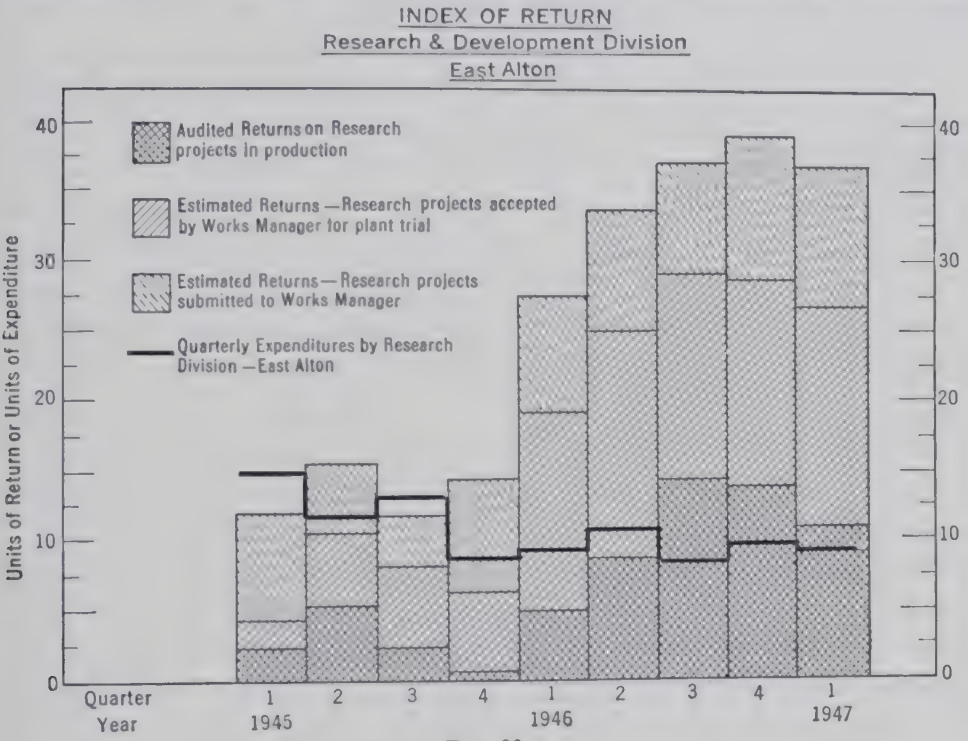

Fig. 30.

From experience this chart seems to speak the kind of language a board of directors understands. First of all, it tells what the company is actually earning, and secondly, it estimates what it may reasonably expect to earn.

Three entries are, therefore, included in the chart for each quarter—

1. The lowest portion of each column shows the Index of Return as determined by the auditors of research projects actually in production.

> 2. The middle part of the column comprises estimated returns on projects which have been completed by the research division, and have been accepted by the works manager, but have not yet been running long enough to permit the auditing division to determine the returns.
> 3. The top part of the column comprises estimated returns from projects completed by the research division, but which the works manager has not yet accepted.

The upper and middle portions of the column give the research director and the members of the board a glimpse of the extent of the backlog of finished jobs which can be expected to "pay off" in the near future.

The total height of the column therefore represents actual and potential returns from completed researches. It also shows that the backlog of jobs is estimated to yield eventually about twice as much return as those currently contributing to the Index of Return.

It is necessary to emphasize that this Index of Return, comprising the sum of these three numbers indicating value of improved process, new products, and improved products, reflects the activity of the development department engaged in work of short-range interest only. It is probably not suitable as a measure of the value of basic research or even of long-range development work.

Experience shows that only a small percentage of work performed by the research and development division can be completed, accepted by the factory staff, and put into operation in less than one year. Probably two to three years is the average time elapsing between the starting of a project and the appraisal of the returns by the auditing division.

The percentage of the budget expended on items which may not pay off for several years, or which may prove to be "an added chapter to the book of science" is probably a decision which top management has to make in an out-and-out gambling spirit. They may designate it by more dignified terms, as money paid out for basic research to insure sound foundations for the later structure of the company. But it is doubtful if any man can predict which of thousands of exploratory experiments are going to turn into profitable industrial operations. It seems unlikely that any businessman could have foreseen from the highly academic studies of Father Nieuwland in the chemical laboratory at Notre Dame, and from the basic studies of Wallace Carothers in the duPont laboratories, that neoprene rubber and nylon hosiery were to be the outcome. Nor did industrial leaders envision that the cyclotron work of E. O. Lawrence in a physics laboratory at California Institute of Technology would pave the way to the world's first atomic bombs.

The recent controversy, which has reached even the halls of Congress, as to the conduct of basic research in the universities, in industrial laboratories, or in government-sponsored laboratories, recognizes the need for fundamental research, but is also aware of the tremendous cost of such work. Many thoroughly competent industrial companies cannot yet harbor the patience necessary to await the long distant pay-off date, especially when it is realized that much fundamental research probably never matures into a profitable operation in the lifetime of the company.

Reference has been made above to the recognition of many companies that 3 per cent of their gross sales is a good amount to spend on research and development work. Actually, a report by the National Research Council gives a survey of American industry, reported in *Research—A National Resource; Vol. 2: Industrial Research,* of December 1940. In Section 4, prepared by Franklin S. Cooper, it is reported that a total of 2,350 companies, employing 70,033 people in technical research, show an expenditure for research which averaged only 0.6 per cent of sales.

Most people who are sufficiently alert to be looking into the question of what amount of money should be spent on research, however, are probably not concerned with the performance of the "average" company. Average performance is of little interest to those who desire to do outstanding work.

In the preparation of the data for this chapter, more than twenty-five companies whose technical accomplishments and high financial rating stamped them as being among the top-flight successful companies, and which comprised a fairly good cross section of American industry were contacted. Most of these companies spend from 2 to 4 per cent of their gross sales for research and development.

It becomes quite important, therefore, for the management of any company, which is consciously striving to maintain a progressive position in the nation's industrial life, to examine its research efforts quite critically, and to question bluntly the adequacy of its research and development budget. To spend 3 per cent of gross sales means a tremendous outlay of money for all large corporations.

Obviously there is no justification for spending 3 per cent of gross sales, or any other ratio for that matter, if this research expenditure is not soundly managed. It is sometimes amazing to note the extent of the business judgment lavished upon other sections of the corporate activities by certain executives, who at the same time are apparently willing to allow a million dollars a year or more to be spent on research without close controls and sharp demands for provable returns.

The fact must, therefore, be faced that research work is expensive.

No other means, however, has been found by modern industry for maintaining a progressive position. The more clearly this is recognized, the more keenly is the research director obligated to prove in clean, crisp terms that the value of the results obtained from these large expenditures comprises an adequate return.

It would seem to be a significant, permanent obligation, which the Industrial Research Institute might assume, to collect data from its member organizations on the ratio of research expenditure to gross sales. The proper conclusions from such a study should provide the strongest basis for allowing the men with large financial interests in industry to form a sound judgment as to the amount they should endorse for research. Likewise, if a number of these companies were to adopt, even tentatively, this plan of calculating the Index of Return for their researches, some correlation might be found between this Index and the improved earnings of the companies. If this were the case, a valuable yardstick would be added to the management controls of both the research division and the board of directors.

If some companies were reluctant to reveal total dollar earnings, the data could be reported as returns per dollar spent on research, and be just as useful for comparative study.

The Index of Return is only one means of recording the *relative* progress of a research and development division from quarter to quarter. A co-operative study as suggested above might readily show an improved technique or lead to a new and perhaps sounder plan for the assessment of research.

How the more complex and vague evaluation of long-range development, or basic research, can be accomplished is, at this moment, a challenging problem in itself—so far unanswered.

It is probable that many companies are going to face quite sharply the question of the extent to which they should engage in fundamental research. The plans which have recently been published for some magnificent research laboratories have already had their repercussions on the morale of research personnel in companies whose activities are mainly in the field of development or applied research.

There is unquestionably a strange glamor which surrounds basic research. It is highly questionable, however, whether most companies, other than the wealthiest and most strongly entrenched, can afford to do much basic research. Indeed, their splendid new research laboratories probably represent the flowering of a long and successful development program, and constitute a truly beautiful embellishment of a company, *after* the directors of the company have become sure of the value of research.

How to Prepare an "Index of Return"

The "Index of Return" consists of the sum of the three following computations:

1. Any saving of material or labor on existing products is to be included in the Index of Return if the savings result directly from the work of the research and development division, and if the change is actually in production. Savings will be calculated only on actual net quantities of the products shipped during the previous quarter. The research and development division may, however, continue to include in the Index, savings on any single project in quarterly portions for a total period of *one year* from the time it goes into production, provided it is still being shipped in the form which resulted in the saving. The "unit saving" calculation will originate in the works manager's office and be audited by the accounting department. Amortization or depreciation of additional equipment used in effecting these savings will be charged into the costs by the usual accounting methods as well as the absorption of unrealized depreciation resulting from non-use of existing facilities. Only direct labor and material savings are to be considered unless the change specifically eliminates overhead charges.
2. When the research and development division creates a new product, it may include in the Index 3 per cent of the total net sales of this item made in the previous quarter providing that this amount does not exceed the net profits realized in the same period, and provided there has been a cumulative net profit earned since the introduction of the new product. Computations will be made for the previous quarterly period, calculated on actual net shipments for these months and continuing quarterly for a period of *three* years from the time shipments started under the profit limitations above.
3. When the research and development division creates an improvement in any one product of the existing product lines that are now in production, it may include in the Index 3 per cent of the net sales made in the previous quarter providing that this amount does not exceed the net profits on the product realized in the same period, plus or minus any savings realized or excess cost incurred because of the improvement. These computations will continue for a period of *one*

year. However, only one credit for improvements on any one item may be claimed for any quarter.

Example of Record of Manufacture Savings

The following data are taken from an actual sheet in use at the Western Cartridge Company, Division of Olin Industries, Inc. This item is only a minor process-improvement study, but perhaps serves to show that real saving can result from relatively small research investments. The return in this instance for one year was approximately ten times the amount spent on the research effort in developing this process.

MANUFACTURING SAVINGS
Division B

Product	XYZ
Research expenditures prior to plant acceptance	$2,544
Date of plant acceptance	August, 1944
Date of shipment of first commercial units	July, 1944
Research division estimate of savings	$3.36 per hundred units (April, 1944)
Estimated saving per unit of product for calculating credit index	$1.79 per hundred units
Source of estimate	Works manager
Accounting department official audit of savings	$1.38 per hundred units
Date of audit	April 2, 1945

Month	*Year*	*No. Units Shipped*	*Savings*
August	1944	122,186	$ 1,686
September	1944	125,412	1,733
October	1944	119,918	1,659
November	1944	131,287	1,814
December	1944	178,507	2,463
January	1945	171,864	2,372
February	1945	182,930	2,524
March	1945	142,965	1,973
April	1945	189,071	2,609
May	1945	111,229	1,535
June	1945	160,349	2,213
July	1945	176,891	2,441
Total Savings			$25,022

Just by way of comment, it may be noted that the research division in April 1944 was optimistic enough to hope that this operation would yield a saving of $3.36 per 100 units. As operation began the works manager gave a more conservative estimate that the saving would be $1.79 per 100 units, whereas after a year's operation the auditor stated that the saving was $1.38 per 100 units. It will be seen that in one year's operation the actual dollar savings on this project has amounted to $25,000 for a research division expenditure of $2,500. Furthermore, these savings will probably continue for several years.

The research division does not often err on the side of optimistic estimates, and the following tabulation for a current operation shows the estimate by the factory staff to be about 40 per cent higher than the research division's estimate of savings. It will be noted that in this second example the accounting department audit has given its approval of the works manager's estimate of 2.1 cents per pound savings, and the total savings for the quarter from June to August 1946 are calculated on this basis. After a full twelve months' shipments a final audit will be made and corrections applied where necessary to the totals reported for each month's shipments. In this instance the return in the first quarter-year's operations is approximately three times the total sum spent in developing the process.

MANUFACTURING SAVINGS
Division A

Product	Alloy Q
Research expenditures prior to plant acceptance	$7,843
Date of plant acceptance	August, 1946
Date of shipment of first commercial units	June, 1946
Research estimate of saving	1.5¢ per lb.
Estimated saving per unit of product for calculating credit index	2.1¢ per lb.
Source of estimate	Works manager
Accounting department official audit of savings	O.K.
Date of audit	September 26, 1946

Month	*Year*	*No. Units Shipped*	*Savings*
June	1946	63,344	$ 1,330
July	1946	309,940	6,509
August	1946	693,771	14,569
Total Saving			$22,408

The first quarter's return from this operation has earned about three times the amount spent by the research division in the development of the process.

CHAPTER XXII

The Research Director's Responsibility in Determining the Company's Patent Policy

The research director by both training and daily activity has a necessarily direct connection with the formulation and the operation of his company's patent policy. It will be obvious that there is much to be said for a corporation whose director of research sits on a level of executive equality with financial, procurement, production, sales, and other managerial personnel, has an equal voice and possesses equal authority. If he does have the status here suggested for him, his work with patents will be immensely aided and his general consideration of the company's wider problems will in turn be helped by his work with patents.

With patent matters added to his already heavy burden, the research director can be forgiven for inquiring quietly whether he could not also be helpful by taking in washing and flat ironing. Be that as it may, it is almost inescapable that he will be called on to plan and carry out the protection of the company's inventions. His work, or that which he directs, produces the subjects of patent protection; in planning his research he will avoid the blind alleys closed by patents already obtained by competitors; his academic and later commercial technical training will have familiarized him, in at least a general way, with patents as the literature of research, and with the strategy of protection. His managerial companions are not likely to have had too much experience along those lines, unless there is a separate patent department or unless he serves a company in which a basic single invention has been built up into a going business through adequately understood patent protection.

This chapter by Albert S. Davis, Jr., Resident Attorney, Research Corp., who acknowledges the review of various portions of the material and valuable suggestions as to the content by Carl W. Hedberg and Robert R. Williams of Research Corp. and Harold T. Stowell of the Washington, D. C., bar.

The Nature of Patentable Invention

It might be well to start this discussion by defining the nature of patentable invention. A cynic might say that a patentable invention is one upon which the Patent Office has not granted a patent in the past, the statutes as interpreted have not denied a patent in the past, and the Patent Office is prepared to grant a patent in the future. Such cynicism is not entirely fair either to our patent system or to the philosophy which lies behind it. A patent is a highly artificial legal right, and the conditions and rules surrounding its issuance are in turn necessarily restrictive and artificial.

It may be suggested that in attempting to assure soundly patentable invention, there are two matters which are, to some extent, within the control of the research director. The first of these is making sure that the true inventor, as nearly as truth can be factually determined, is named on the application. This is not always as automatic a process as it might be. Another cynic has said that, when his clients are sued for infringement by a corporate patentholder in whose laboratories the patent originated, he always sets up as a first defense that the patentee is not the true inventor.

There are two common situations which produce this difficulty. The first is that in many cases a director or section chief outlines and assigns a problem, and sketches the line of attack to be followed, and the research worker obtains the patentable result. In such a case there is a neat question of the extent to which the details of the planned attack on the problem in and of themselves constitute the answer to the problem (i.e., the invention). Conversely, there must be appraisal of the extent to which the research worker chose the method of attack, refined the procedure within that method, deviated therefrom, and used his own originative ability. When this situation arises (and it is inherent in the modern research organization), one cannot emphasize too strongly that protocol, relative reputation, and personnel differences must be thrown out the window. What the patent counsel will ask is a sober factual account of what was actually done by whom, as supported by notebooks and pertinent memoranda. He should be given this in good faith.

The other problem of naming the true inventor commonly comes up when a research team evolves patentable results, and co-invention arises. Here the patent counsel will have before him the difficulty of showing that two or more men had a flash of genius simultaneously (if the Supreme Court sticks to its recent language about the character of the inventive act) set against the difficulty of excluding from the application any man who contributed substantially to the novelty in the invention. If the research team operates with great coordination and exchange of thought, so that the development of inventive thought proceeds at essentially the same level with each of the men simultaneously, the separate notebooks will presumably make out a much better case for co-invention. (Even then, of course, the strictures that certain courts have recently put upon the quality of invention required of organized corporate research may be troublesome.)

In each of these cases the research director has a real opportunity to smooth the path toward soundly patentable results. The problem is basically one of human management, not of law or science.

The second set of criteria where the research director can be of factual help in assuring patentable invention might be called negative tests. The statute and rules require that the patent applicant be able to show that certain things are not true of the invention for which he claims protection. Those negations which, taken as a whole, are referred to as *prior art*, are of course beyond the control of the research director, save to the extent that he can eliminate certain lines of attack as being patent-controlled by others or available to the world at large. Others of these negations, however, are controllable.

For example, an invention, to be patentable, must be "not . . . described in any printed publication in this or any foreign country . . . more than one year prior to his application." The research director will keep in mind that any technical writings emanating from his department should be cleared with patent counsel or the patent department before submission for publication. The same caution applies to the delivery of lectures which may be reported by the scientific organ of the group addressed. What will be more difficult will be the need for keeping the sales and promotion departments from covering the invention too thoroughly in their literature before the application has been filed. In the interest of keeping peace in the house, it will often be found that the quietest way to achieve this is to establish it as policy in the patent policy group, and then let those responsible for patent prosecution enforce it.

Again, the invention must not have been "in public use or on sale in the United States for more than one year prior to his application." Here, again, there is a distinct possibility of conflict of patent management with sales and promotion management, and the matter is best handled through the patent policy group and those responsible for patent prosecution. For his part, once the policy has been established, the research director will do well to police the output and disclosures of his laboratory in such a way that circulation of samples or information to friendly concerns and technicians is on an experimental basis. This does not mean that it is enough to write a letter saying so. A table is not a dog simply because it has four legs, even if one calls it a dog. When there is a disclosure or forwarding of material for experimental purposes, there should be, at the very least, a requirement of experimentation and reporting of results by the recipient. Implications both of commercial routine and of "do with it what you will, we have found it interesting" should be strenuously avoided.

Reasons for Patent Protection

The research director's generalized ideas about patents will, of course, vary with his own philosophies and experience. For the most part, however, a few general principles seem to apply.

1. *The director should keep in mind the reason for creating a national patent system.* The patent system is commonly explained as designed to encourage persons having inventive skill to use it for the good of the general public. The inventor, in his patent, discloses something new and useful—his reward is the right to exclude others from making it or using it for seventeen years, except upon such terms as he sees fit to set. During that time, occasional examples of "shelving" to the contrary, the public has the benefit of the invention, at a price. At the end of that time, the public enjoys free use of it. It follows that the patent is a monopoly, of a limited and special type.

This form of monopoly should not, of course, be confused with the historic type of English monopoly, which was simply a grant to a court favorite or high bidder of the sole right to deal in some commodity such as pepper, or with modern industrial monopoly, which is in effect the gathering together of control over a dominating sector of an industry, in exchange for which the public usually receives only the somewhat mixed blessings of integrated and hence more efficient industrial organization.

Regardless of what legal devices have been or can be devised to elaborate this, the patent system is thus *intended* to be a very simple thing. Its usefulness will, generally and in specific cases, be limited in direct proportion to the degree of divergence from this central idea.

2. *The director should keep in mind that in many cases only patent protection stands between his company and bitter competition.* Most companies start in a small way with a new idea. The majority of new ideas within an established company also start in a small way. Unless the ideas are patented, they are unprotected against copying by a competitor who discovers them by honest inquiry, and is all too often better equipped financially and technologically to exploit new ideas than is the company whose men originated them.

It is only within the narrowest limits that one can hope to protect an idea as a "trade secret." Anything that can be flatly imitated or reproduced, such as an electrical circuit, a bearing, a pump, or a new chemical compound, is not protected in any way against honest imitation or reproduction, once it has passed into the channels of trade. It is, of course, theoretically easier to keep a chemical process secret, but where technical knowledge is as widespread as it is at present, even such processes are very poorly protected in the absence of a patent. As the law of trade secrets now stands, the imitator can generally be enjoined only where he learned the art by fraud, by breach of contract or trust, bribery, commercial espionage, and the like.

It has been suggested that if the courts' present tendency to invalidate patents continues much longer, chemical process companies, at least, may decide not to take out patents, but to keep their work secret. Whether any such secret can, as a practical matter, be kept for seventeen years is a moot question.

3. *The director should know why his company wants to take out patents.* The drives toward patenting of course are varied. The great common factor in patenting is undoubtedly desire for protection against competition. With a great many individuals, and some companies, there is a rather indefinite feeling of intellectual or industrial prestige associated with the possession of patents. Many companies tend to take out patents because of an equally indefinite

feeling that it is general practice and therefore a "good idea." In more detailed cases, patents serve as trading material to secure rights from other companies, to prevent infringement suits, to round out a process, a product, or a line of goods, and to suppress competition, which is quite different from protection from competition.

What the research director will have in mind will be a *mélange* of all these and many other factors. What he will try to do will be to settle on what his company's general and specific problems are, and adapt its method and scope of seeking patent protection to the problems.

For an example, we may take the established old-line company that desires to develop a new line of products entirely distinct from its normal activities. It probably will have relatively substantial venture capital and an adequate sales and promotion organization, compared with the new company or the individual starting out for himself. Unless the new product has enormous novelty appeal, however, or its production is attended by so much know-how as to amount to a trade secret that will be safe for a reasonable period, management will normally hesitate some time before risking a large amount of money. Patent protection can afford the necessary margin of safety.

4. *The director should keep in mind that patents are only a tool to serve production, not an end in themselves.* No patent is better than the art which it claims, or the actual production technique that carries the art into being. Many a research department and its patent appendages have been defeated because the highly technical disclosures of a patent have been assumed to be the art that was actually commercially useful. Generally speaking, the first two to five years of a patent's life will see gradual commercial reduction to practice which is much more important than the actual or constructive reduction to practice that concerns patent lawyers. Other research departments have foundered in a sea of patents, the varying values of which are obscured by the fact that they grant an exclusive right.

5. *The director should bear in mind that abuse of the purposes of the patent system results in weak patents, generally and specifically.* It is impossible in a comment of this scope to begin to enumerate the various aspects that this abuse may take. One of the most common is the practice, with companies that have not thought out the why of what they want to do with patents, of seeking patents

on everything that emerges from their research sections. If claims are drawn narrowly enough, and there is any "invention" at all involved, it is usually possible to obtain patents on work having any substantial tinge of scientific respectability. Those patents will not, under prevailing conditions, stand up under the test of court litigation. It follows that they not only delude the holder into a false sense of security, but that their eventual collapse is taken as a sign of weakness in the patent system itself.

There is nothing magical about these points of focal thinking. Any research director who has worked much with patents can readily suggest many others—for instance, consideration of the fact that, since patent is a highly artificial form of legal property protection, careful observance of the legal formalities attending its creation and life is vital. What these points do emphasize is the fact that a research director must think about patents broadly—strategically, if you will.

Formulation of Patent Policy

Granted, then, that a research director is willing to assume this responsibility not too unwillingly—how can he and his company best formulate a patent policy and put it into effect?

The tendency toward formation of managerial groups to deal with research matters is well recognized in management practice today. It is to be hoped that this tendency shows that other departments are not only paying tribute to a vague importance in research but are also attempting to understand and evaluate what goes on in the research division. An expert in research management has given an excellent summary of the best groundwork for such understanding:

> An old established engineering and industrial specialty manufacturing company in New England was principally interested in recasting and expanding its technical research and development activities with an eye to postwar readjustment. The president of the company took the rather unorthodox but highly progressive viewpoint that we should organize a postwar committee and sprinkle the representation generously with junior executives from research and development, as well as marketing and production. The president would then have a "man market clinic" in which he could evaluate the coming executives in the organization in terms of their individual and collective judgments as recorded in the minutes of the postwar committee.
>
> For over three years this committee has met regularly each month, presided over by the chief executive of the company, and has made a

> thorough and comprehensive analysis of the entire technological foundation of the business. A by-product of its accomplishments has been the establishment in the chief executive's mind of the significant fact that on the management level at present there is a majority representation from the nonproductive departments of the company (such as legal and accounting) and to put it in his own language: "I want this company dominated in the postwar competitive era by engineers and technologists, and not by bookkeepers, accountants, and legal experts. This is an engineering specialty business; our management must understand more than the balance sheet. It must understand the 'technological guts' of the business." [1]

Granted that such a research committee has been set up, the broad aspects of patent policy and company patent matters can best be handled by a regular session scheduled for such a purpose. It is somewhat less preferable to devote part of each meeting to patent matters, since there is a natural urge to put them to one side as difficult to understand, technical and specialized in their nature, or artificial.

If a company is large enough, it is desirable to have a separate patent policy committee which considers both policy and major patent matters. Such a committee should present a composite of company departmental interests. There should be enough duplication of personnel with the research committee, or a strong enough representation of top personnel, to assure that its recommendations will not be pocketed or filed as "interesting." In the new or small company the committee will probably be the usual council of war that fights the company's battles.

It is advisable that this committee not sit too frequently. If its meetings are at intervals, it will tend to concern itself much less with the *minutiae* of current applications, and will devote more of its attention to major considerations such as general scope of patent protection, the directions in which successful research will be best rewarded by adequate patent protection, or the most advantageous alignment of the company's patent interests with those of other companies.

The research director carries much of the responsibility for directing the committee's course. It is to be expected that in the discussions that arise, his recommendations will be given substantial weight when they deal with patent matters, just as when they deal with research matters. His ideas, of course, may be subject to a further review that is not imposed on other management heads: clearance through the patent department and, on occasion, through the legal department as well, if the company has such departments separate. This does not imply inferiority on the part of the research director, but simply that every man has his specialty.

If the company has a large enough staff, the research director should adopt a policy of steering away from routine. It is wise to put the details of collaboration, of patent application processing, and the like as far as possible in the hands of assistants, reserving for himself the drawing of the lines of applied policy and good judgment within which they will operate. Willingness to delegate such responsibility is commonly recognized as a hallmark of good management. It is a good thing for the average research director to be familiar with patent technicalities, but it is even more important for him to be able to select a junior upon whom he can rely for applying technicalities with good sense to decisions on individual applications.

Evaluation of Patentable Ideas

In many cases, the research director's task at meetings of the committee will be to furnish data from which conclusions may be drawn. Consider a test case and refer for a moment to four extremely pertinent factors of patent policy: (1) what and how to protect, (2) what chances to run or avoid, (3) how to make patents aid the research program, and (4) how far to collaborate with competitors. The research director's primary concern is with the first and third of these. Assume that a company is making an antiseptic having a short shelf life, presently manufactured by a non-patented five-step method. Assume further that company research develops a new and patentable production technique (*a*) cutting the method to three steps and giving higher yields, (*b*) involving a wholly new intermediate which is itself patentable, and (*c*) using an inhibitor giving longer shelf life. Under these conditions, management tends to sum up the result by a delighted but hasty, "We can make it better and sell it cheaper."

It rests with the research director to explore and explain the why of this conclusion. His first concern in this assumed case will be to evaluate, with production management, the saving which will come from the shortened process. He will supply the details on materials, treatment times, and yields; production will translate this into cost, and sales and promotion into price.

It is submitted that proper management consideration of the value of the new process and improved product goes further than this; that it should, as a matter of routine, explore rather fully the particular patent policy to be adopted for the invention and the effect of such protection on the general patent policy of the company; and that the responsibility for initiating and guiding the discussion primarily devolves on the research director.

He will think over the possibilities of further research in his own laboratories, and more important, in competitive laboratories, studying their recent patents and publications for clues. He will consider whether the invention is complete, or whether the work has evolved some general rule of chemical procedure that opens the way for a line of work of indefinite scope by which his company's new competitive advantage will be lost. In the latter case he will briefly debate whether to recommend that the process be held as a trade secret, and, in all likelihood, abandon the idea. He will then plan, for direction, scope, length, personnel, cost, and patent protection reported to him to be available in the event of success, the line of further inquiry upon which his own laboratory should proceed, with an eye to what competitors' research departments are most likely to do when they learn of the innovation. He can fairly expect that the time normally required for passage of an application through the Patent Office, entirely without any of the artificial delays which have been so bitterly condemned in investigations, will protect his company while it sets up marketing devices for the invention.

It may well be objected at this point that the discussion concerns the function of the research director generally, rather than with respect to patent policy. That is precisely the point intended to be made. A company's patent policy must be intimately related to the discovery or production of marketable materials, and to the production and marketing of discovered materials. Patents do not hang nakedly in the air as interesting legal phenomena.

Simultaneously with the steps described, the research director will be planning in its general scope, step by step, the patent protection the specific situation calls for, asking the patent department or patent counsel for an opinion as to how much protection can be obtained, and evaluating its competitive effect. The productive patent policy is one that helps to market products by making cheaper production possible, by confining such patents to the company alone, by giving the company some price advantage if the patents are licensed to competitors at a royalty, and by using the patents as trading points to obtain licenses under useful patents held by competitors. While the first of the above points may loom largest in deciding what patents and claims should be sought, all must be taken into account, and full discussion of them at management meetings is of equal value to the research director and to other departmental heads.

What has been said in this outline of a typical problem does not mean at all that the research director or his department should swallow the patent department and its personnel or outside patent counsel. It emphasizes rather the requirements that he know patents intimately, *not technically but structurally*, and that his is the responsibility for guiding the invention from the laboratory to a logical place in the company's patent edifice. We are overburdened with pseudoforms of the engineer today, but the research director in a very real sense should be his company's patent engineer.

It cannot be expected that his work to this end will follow the same pattern no matter what the character of his company may be. As has been implied, especially in the new or very small company, he will probably have to do everything but take in washing. However, he has actually a greater opportunity in a company that is in the early stages of corporate development than in a larger established company where he will usually sit with persons specializing in patents and of at least equal ability.

The Research Director's Role in Litigation

In the formation and application of general company patent policy, then, it has been recommended that a great deal of responsibility rest on the research director, who will work largely on the basis of "information received." This is essentially because he is usually fitted by inclination and always equipped by his activities to co-ordinate production of inventions with their tactical use by the company. Corporate patent policy, however, is not by any means confined to planning for and obtaining patents.

In the evaluation of whether patent infringements should be chanced or avoided, the research director's position is somewhat reversed, and he may be most useful as a source of technical information. This is suggested for several reasons.

First, the impact of adverse patent litigation or infringement by another company reaches not only the company's general patent policy but its financial and possibly its business structure as well. Both as a matter of sound management and common practice, the individuals in financial and top management posts should make the decisions on patent litigation or infringement. Such decisions if handled by group action, will probably be made, authorized, or reviewed and approved by the general management committee. Since this type of decision will affect patent policy, it should be preceded by a report from the patent committee or patent session of the research committee, and followed by a review of its effects. The research director will play a leading role in both reporting and reviewing.

Second, the appraisal of the pros and cons of patent litigation is something that calls for special skills in patent and general law. To take a typical case, assume that a manufacturing company holds patents on a chemical process distinguished from the usual method of manufacture by use of a special catalyst, and that it can therefore undersell competitors markedly on its end product. This advantage it has used thoroughly, with the result that several other companies have abandoned the line of business. The company then suddenly finds that a competitor is selling the product both commercially and on government supply contracts at a slightly lower price. It finds, though, no mention of the method of production in the technical press, and cannot secure information as to the process used by its competitor, but is 90 per cent sure that a patent infringement is being carried on.

The following questions arise at once. How can evidence of infringement be secured? What risks of a charge of industrial spying would be justified? What about an examination before trial? Is the patent strong enough to justify a suit? Is it likely that the competitor has an application for an improvement patent under way, which would be valuable as trading material to the competitor even though dominated by the company's own patent? Should an injunction be sought, and relief disclaimed as to activities for the government? Should damages be asked? Should suit be brought in the Court of Claims? Is there a choice of places where suit can be brought, and which court has the most favorable recent run of decisions? Need formal notice of the company's patent be given to the competitor? If suit is brought, will the Department of Justice intervene, and with what probable results?

A great deal of the scientific information needed to answer such questions must be given by the research director. It is submitted that his responsibilities should not go further.

Stimulating Research

Perhaps the research director's most important role is his effort to make the company's research program more productive through the use of patents. Certainly he is here least able to rely on the head of the research committee or the patent committee, for in most cases he will be dealing with matters entirely under his own jurisdiction and in his own department.

It should be obvious by now that a company's patent policy can serve to stimulate research. Fundamentally, the research director's job in this direction is a curiously dual one: to drive home to his staff—directly or through personnel chief—and to make them see that not patents but inventions, in the sense of the discovery of knowledge, are the end of research. The patent is really the expression of what has been done or what can be done.

In emphasizing the importance of patents, it is advisable to point out to the research worker at an early stage in his exploration of a new problem—preferably when it is first outlined—the tactical position that past patents occupy, the deficiencies of the art shown in both their disclosures and claims, and the protection that would be available if the work is carried through successfully. If the research worker is at all prolific, his contacts with patent values and procedure through the pattern of collaboration with the patent department will be equally useful. In such discussions it is often unwise to consider the position that any patent that may be obtained will play in the company's general patent structure. Emphasis on that angle is likely to lead some workers to feel that the company's fate hinges on the success of their efforts, and to assert vociferously and unduly the value of their patents.

It will also be necessary for the research director, through appropriate channels, to prevent members of his staff from becoming so interested in patents that they lose primary interest in actual research. A great deal of the most important information that comes out of an industrial laboratory is totally unpatentable: proof that apparatus or methods will not work or that suggested processes are not economic, fine distinctions between old art and new developments, or slow progress in understanding why a problem is difficult, and partial predictions of coming knowledge. Practical examples might be, for instance, discrimination in quality of raw materials, choice among unpatented processes, perspective with respect to kindred arts, and appraisal of the possibilities of competitive products. To illustrate, it would be extremely unfortunate if a research worker in synthesis of an antibiotic were to become enmeshed in the technical subtleties of whether a patent can be obtained on such a product or only on the process by which it is produced. The director will have enough troubles on hand without arguing patent law with the research staff.

It is a valuable thing for the research director, perhaps with the head of the patent department, to sit down with the laboratory staff members and discuss two things: the nature and function of patents, and the general direction which the company's patent policy takes. In such a way, their general importance to the company may be stressed without too strong a likelihood of running into individual personnel problems. Some companies have found it advisable to conduct regular seminars or set up classes for this purpose. Unfortunately, institutional courses along these lines are rather rare—their establishment would be useful both to the undergraduate technical student and the industrial research worker.

A number of research directors feel that the effect of patent considerations may be to mar research rather than to improve it with respect to scientific quality, and to create jealousy, secretiveness, and failure to co-operate among members of the staff. Some directors feel that patent considerations may produce an undue respect for the great technical advantage of early Patent Office filing and with it a tendency to rely on slipshod guesswork, since there is no serious penalty on the filing of patent applications that are partly untrue. They sum up the benefits of patents by noting that they require that the research worker keep up to date on the existing art as revealed by the patent literature. To this they add the need of immediate witnessed recording of concepts, ideas, or inventions when first conceived. When those steps have been taken they urge that one can, so far as the domestic patent situation is concerned, take reasonable time to consolidate experimental work and make sure that w filed is scientifically sound.

Other directors feel that patents can serve as major stimul research program that is productive through protection of r against competition, building up the company's business as an grated whole, creation of an *esprit de corps* among the researc sonnel, and establishment of bargaining factors for trading situ with competitors or connected industries. Beyond these, ther be a sensed, but seldom expressed, possibility of technical adv

Patent literature, though intermixed with much misinform is the greatest storehouse of scientific information that the holds. The entire development of each of the industries is s out in it. Nothing is more rewarding than intensive study o disclosures made in any given field, not with an eye to w claimed, but with the purpose of seeing what is not claimed be it could not be done, or what is claimed and now can be done b A patent should usually have another stimulative effect on th search body that originated it—a lively sense of dissatisfaction the claims obtained and with the technical pull and haul accom ing its progress through the Patent Office. Fruitful research nothing but the process of useful improvement, the obtaini patents is a constant reminder of what "useful improvement" m

It will be useful if a studied attempt can be made to have pa serve as a spur to a competitive spirit in the laboratory in relati the research personnel of other companies. Most directors ar too well aware of the professional kudos that attach to "first pu tion." As has been seen, however, in the commercial field inve means very little unless it is protected by patents. According may be counted on that a publication by a non-institutional res worker will be preceded or followed by patent applications, in cases out of ten. No industrial research laboratory can say, that it will catch up with the opposition. Unless managemen trade a license out of its competition, appearance of a public often means that a door has been shut.

It will stimulate painstaking and end-minded research if th rector will inculcate two principles: first, that somebody else is probability working on the same problem, and, if he breaks it can close the door; secondly, that the work must be so method one, so logically organized, and so carefully reported that it will ithstand the strain of an interference. Properly utilized, patents hould be a stimulus to better laboratory work.

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CHAPTER XXIII

Pattern of Collaboration between the Research Department and the Patent Department

In a large measure, the pattern of collaboration between the research department and the patent department will depend upon th size of the company, since that will dictate the number and activit assignments of available personnel.

In the smaller company, it is likely that the research director ma be called on to do a major share of the patent work himself—at leas that which does not involve actual appearance before the Patent Office, court work, or the drawing of agreements. Those aspects wil often be handled in part by patent counsel and in part by the company's counsel. The advantages of such a division of authority ar those obviously found in specialization, in nearness to the Paten Office, and in leaving the research director relatively free to direc research. The disadvantages are that occasionally the relativel small account of a small company, even though adequately attende to, may not receive the same thorough treatment or attention of senior counsel which a larger company would get, the relatively hig expense of frequent consultations with the company's representatives, and the fact that an outsider cannot always have the same intimate knowledge of a company's affairs or interests that the company own personnel possess. Unfortunately, the research director of small company, unless singularly gifted, is himself not to be traine for *detailed* patent application work. In many instances, he is eithe

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This chapter by Albert S. Davis, Jr., Resident Attorney, Research Corp., wh acknowledges the review of various portions of the material and valuable suggestion as to the content by Carl W. Hedberg and Robert R. Williams of Research Corp. an Harold T. Stowell of the Washington, D. C., bar.

the key inventor on whose work the company is built, or its top technical man with patent experience. He is usually so overloaded with administrative or even personal laboratory work that he cannot do an adequate job on patent applications. He faces even more difficulty in approaching the purely legal side of patent work. The use of outside patent prosecution counsel is therefore probably preferable, with the research director keeping in close touch with what goes on. The use of outside legal counsel is almost mandatory. Under such conditions, reliance on a sound firm of patent lawyers qualified to practice law offers the best chances of all-around success.

A company of medium size is, as a matter of traditional corporate organization, more likely to have a legal department than a patent department. It is usually not advisable to call on existing legal personnel to handle patent prosecutions. While there is no insurmountable obstacle to a lawyer of proper aptitudes being highly successful on turning to patent work as a new activity, the necessity for a technical background in his education or training, and the intricacies of Patent Office practice, are formidable hurdles.

Retaining of outside counsel presents the same difficulties that a small company faces, but in a much smaller degree. Because of a more continuous flow of applications, patent counsel becomes more closely acquainted with the company and the tenor of its affairs, and is likely to take a more personal interest in them. The same factor makes it even more unlikely that the research director can spare the time for patent prosecution, or carry it on adequately, and such companies are usually more successful with outside patent counsel. This leaves the company's legal department free to handle the legal aspects of its patent matters. For the most part, these will consist of contractual work. While such work is specialized, there is nothing in it that the average lawyer cannot acquire by study. When questions of patent litigation, such as infringement matters, arise, however, the company attorney for a medium-sized organization will often ask for the assistance of specialist trial counsel. He is justified in this for, by occupational training if not by inclination, he is likely to be a "desk lawyer," and in trying an infringement case he will run into many of the same difficulties he would meet in the prosecution of a patent application. This tendency will be stronger in the future if the district courts continue to take the recent cue of the Supreme Court [2] and concern themselves, in infringement cases, largely with the technical question of patent validity and somewhat secondarily with the issue of infringement.

The large company has before it the problem of making an organization work rather than of selecting a type of organization, for sufficient personnel will be available to have both a patent prosecution department and a legal department devoted in part to patent matters.

Costs of Patents

Unfortunately, it is impossible to predict with any considerable measure of accuracy what the expense of a patent program will be. An ordinary uncomplicated application, in the hands of competent outside patent lawyers, might cost from three to five hundred dollars, aside from drafting and the Patent Office fee. Such a charge would allow for a reasonably full search, drawing the application, and half a dozen conferences and amendments leading to final issue. In these days of frequent interferences and Patent Office insistence on divisions, however, one can expect that a number of applications are going to run into more money.

Company patent counsel are usually capable, like any other personnel, in direct proportion to what one pays for their services. An average starting salary range, depending on such diverse factors as intrinsic ability, education, age and experience, interest in the employer's special line of endeavor, the amount and type of work to be done, and the state of the personnel market at the time, might be about five thousand dollars a year.

It follows that to some extent a company whose patent policy contemplates multiple patent protection, or whose applications are of the type lending themselves to division or requiring a number of continuations-in-part, will look with some favor on retaining a full-time company patent lawyer, or developing a small patent department. The patent salaries, of course, will be increased by wages or time charges for special stenographic charges, drafting, and overhead, including office space and an adequate library, except in larger cities.

Collaboration with Patent Department

In all of these cases, the principal problem before the research department is, of course, one of collaborating with associated personnel in order to get the best possible results. The importance of this to the success of the company itself is obvious. On a less altruistic level, the research director has every reason to wish as close a pattern of collaboration as can be obtained. It is of the utmost importance that there be mutual confidence and co-operation between the research director and the patent attorney or patent department. The patent man holds in his hands the *legal* fruits of research. An attempt on his part to make capital for himself, to interfere with the research director's organization, or to pass the buck when protection cannot be obtained or fails, is a very difficult thing with which to deal.

The ideal organization will be one where patentable inventions are detected and appraised as thoroughly and promptly as possible, and flow regularly and smoothly into patent applications; where the patent attorney (or department, the terms being used interchangeably in this chapter) is given full information and assistance for securing the best claims possible, and knows not only what specific protection is desired, but how it can be most helpful to the company's policy and what the specific and general policy is; where the patent attorney can from time to time uncover an invention not detected by the research department; where the legal department is fully advised as to the factual motivations behind each contract, assignment, or license; and where the persons having supervisory research, patent, and legal responsibilities can work smoothly in discovering, appraising, and handling patent difficulties with other companies. One point too frequently overlooked is the advisability of seeing to it that this spirit, and as much of the pertinent information as is at all possible, be sent down the personnel chain. Only so can replacements be trained, and more important, only so can juniors get the same feeling of united company effort that one hopes to secure at the top. A company is not secure if a train wreck could seriously weaken its research-patent-legal axis, or for that matter any of the other multiple links of company management, such as production-promotion-sales.

Although this chapter cannot give full description or consideration to the various mechanisms for achieving this ideal situation, the more important ones can be indicated. It is fundamental to realize that these are only mechanisms, and that they have no value at all unless they are made to work. They do have the advantage of lessening the chances of losing inventions or patents, of minimizing

friction, and of so regularizing the course of handling inventive ide
that the element of memory is reduced to a minimum.

Detecting the Invention

In most cases, the research worker will have been assigned to
specific task to secure a given result. At some point in his work,
successful, he will secure the result in recognizable form. It
highly likely that, at that point, his findings will not be demonstrab
with sufficient regularity to justify immediate filing of a patent a
plication. In patent language, he will have conceived his inventio
As a matter of technicality, he may have reduced it to practice. Us
ally there is still necessary a further reduction to practice, wholly fo
inventive rather than commercial production purposes. As an ex
ample, take a worker assigned to investigate new catalysts for a typ
of reaction. He observes, with one of the catalysts, occurrence o
the desired reaction. He obtained only a 5 per cent yield, and onl
in three trials out of four. The invention has been conceived, tha
is, the use of the particular catalyst to obtain the desired reactio
He must now investigate to get the best general ranges of operatio
(temperature, pressure, time, etc.) before he is ready for a paten
application. It will be equally necessary for the production depar
ment, in all likelihood with the research worker's assistance, to mak
a selection within those ranges before the process is commerciall
adequate.

Yet even at that point the importance of an adequate system o
records is apparent. Sound collaboration between the research an
patent departments will emphasize detection of the invention a
early as possible. Responsibility for the detection rests primaril
on the individual research worker, with his director (or someon
definitely assigned to the duty) reviewing frequently to determin
whether something has been missed.

The necessary mechanism can often be worked out throug
the means of routine research-result reports made at frequent inte
vals. It consists of (1) a system of periodic automatic checks, (2
system of invention reports, and (3) a regular review of the wor
preferably by someone not intimately associated with it but thor
oughly familiar with the scientific or technical background.

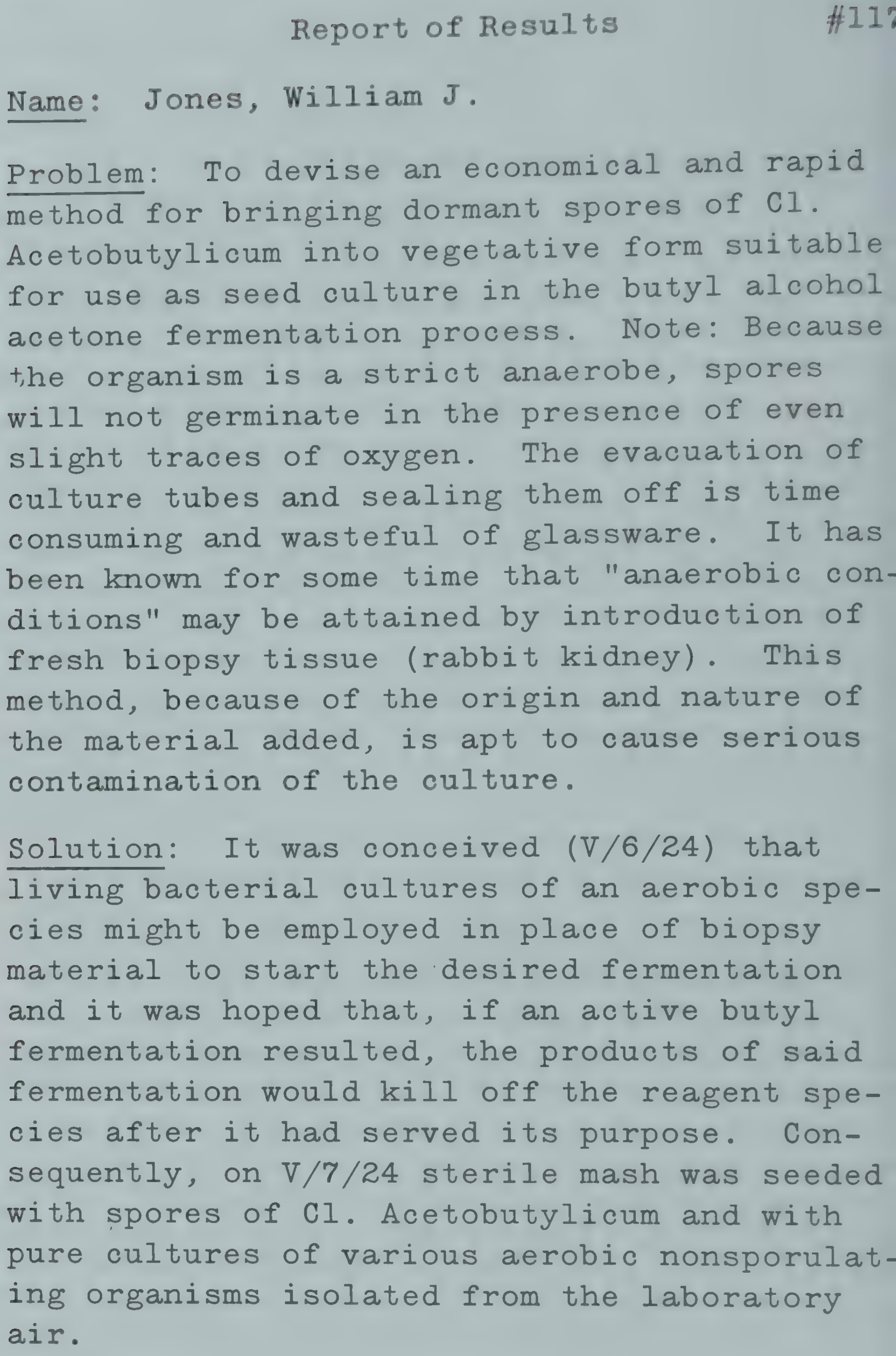
The first step should consist of a regular report, either noted b
the research director, after conference with the worker and examin

tion of his notebook, or handed in by the worker. The form of the report is unimportant; its object is to state (1) the problem on which the work is being done, (2) the end sought, (3) the general line of attack, (4) the specific line of attack followed in the report period, and (5) the results, if any. The moment that the results become favorable, action is necessary.

That action should take the form of a special notice, which should be prepared by the research worker at once if he is in an interval between the periodic reports or conferences on them. The purpose of the notice should be to state as simply and clearly as possible what he has done. No attempt should be made to word it in patent-claim language. The reasons for terseness are (1) to avoid any implied limitation upon the patentability of the invention by a possible showing in the record form that the inventor did not fully appreciate or understand what he had done, and (2) to allow the research committee, and more particularly, the company's patent department, full opportunity to appraise what claims can be sought and secured and what further work is immediately necessary. It is the primary responsibility of the research worker to get this report in the moment that he thinks it justified, and it is the equal responsibility of the research director to see to it that the report is filed on time. Figure 31 illustrates such a report.

The form should be distributed, as indicated, to the research director, the patent committee or the patent session of the research committee (so that it will come up on its agenda automatically), the patent department, and to other persons interested. Co-workers and witnesses present during the work should discuss the work with the inventor and sign and date the clause at the bottom. Upon receipt, the research director will take such further steps as he believes to be called for, including in any event full discussion with the inventor, followed by signature and dating of the witness clause.

Simultaneously, the patent department will be making a first rough search to determine patentability, and will report its recommendations to both the committee and the research director. These will normally comprise (1) a brief review of possible anticipations, (2) a brief review of the scope of claims likely to be allowed, (3) criticisms from the patent point of view, possibly including suggestions toward work which would result in better claims or sounder reduction to practice, (4) an appraisal of patentable possibilities with re-



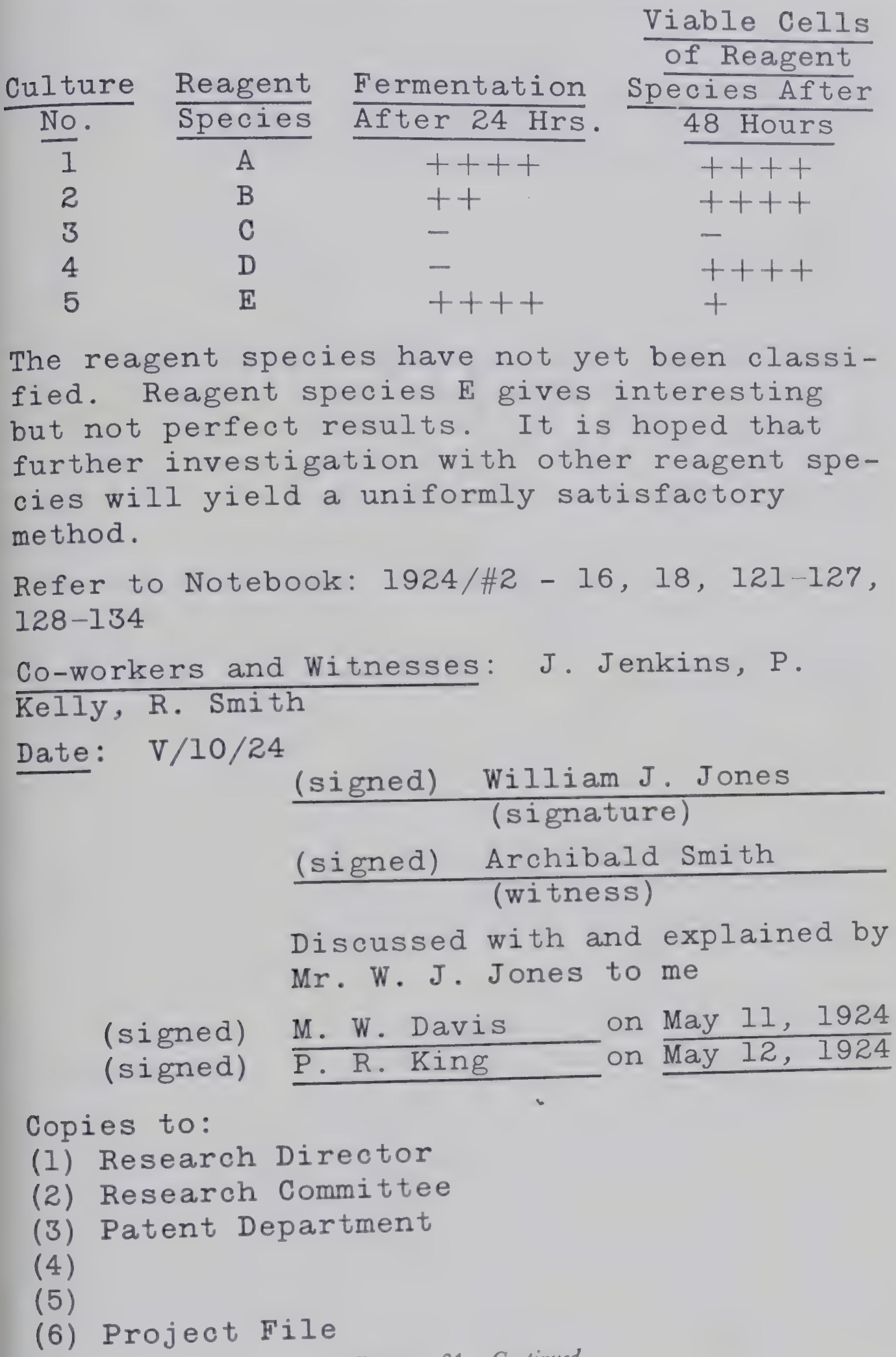
Report of Results #11

Name: Jones, William J.

Problem: To devise an economical and rapid method for bringing dormant spores of Cl. Acetobutylicum into vegetative form suitable for use as seed culture in the butyl alcohol acetone fermentation process. Note: Because the organism is a strict anaerobe, spores will not germinate in the presence of even slight traces of oxygen. The evacuation of culture tubes and sealing them off is time consuming and wasteful of glassware. It has been known for some time that "anaerobic conditions" may be attained by introduction of fresh biopsy tissue (rabbit kidney). This method, because of the origin and nature of the material added, is apt to cause serious contamination of the culture.

Solution: It was conceived (V/6/24) that living bacterial cultures of an aerobic species might be employed in place of biopsy material to start the desired fermentation and it was hoped that, if an active butyl fermentation resulted, the products of said fermentation would kill off the reagent species after it had served its purpose. Consequently, on V/7/24 sterile mash was seeded with spores of Cl. Acetobutylicum and with pure cultures of various aerobic nonsporulating organisms isolated from the laboratory air.

FIGURE 31



Culture No.	Reagent Species	Fermentation After 24 Hrs.	Viable Cells of Reagent Species After 48 Hours
1	A	++++	++++
2	B	++	++++
3	C	−	−
4	D	−	++++
5	E	++++	+

The reagent species have not yet been classified. Reagent species E gives interesting but not perfect results. It is hoped that further investigation with other reagent species will yield a uniformly satisfactory method.

Refer to Notebook: 1924/#2 - 16, 18, 121-127, 128-134

Co-workers and Witnesses: J. Jenkins, P. Kelly, R. Smith

Date: V/10/24

(signed) William J. Jones
(signature)

(signed) Archibald Smith
(witness)

Discussed with and explained by Mr. W. J. Jones to me

(signed) M. W. Davis on May 11, 1924
(signed) P. R. King on May 12, 1924

Copies to:
(1) Research Director
(2) Research Committee
(3) Patent Department
(4)
(5)
(6) Project File

FIGURE 31—*Continued*

spect to other patents held by the company, and (5) a recommend
tion as to whether a patent should be sought. Acting on the paten
committee's report, the research director in the ordinary course wi
either order further work done, or recommend to the committee tha
a patent be sought, with or without further basic work or improv
ment.

Parenthetically, it may be noted that from time to time a r
search worker will develop a line of thought which is not directl
connected with or useful in his immediate problem, but is wort
investigating. This is more of a research administrative than a pa
ent matter, but it is likely to be a useful practice to encourage th
invariable submission of such observations to the research directo
using a simplified form of the "report of results" in Figure 31

Protecting the Invention

At the stage when a patent application is decided upon, the mos
active collaboration between the inventor and the patent depar
ment should be encouraged (subject to final review of scientific find
ings by the research director) as a full statement of the invention an
the facts surrounding it is in order. If independent patent couns
are used, they will probably have their own ideas on what form th
statement should take, and their ideas should be given considerabl
deference. Men doing such specialized work naturally fall int
usages and forms that fit in with their methods of thinking, and ac
ceptance of this factor makes for better work and better relations

If no preference is expressed, however, or if merely internal pa
per work is involved, the following list of items which might fit i
to such a form is suggested:

(1) Name of inventor.
(2) Names of associated personnel.
(3) Date of invention.
(4) Precise description of invention.
(5) General description of general problem.
(6) Brief reference list of prior art and publications known to inventor.
(7) Steps followed by inventor in his research work prior to making the invention.
(8) Brief outline of commercially competitive art.
(9) Statement of place it is believed invention, if patented, will hold in company's patent structure.
(10) Scope of patents believed desirable.
(11) Plans for further work.

To this should be attached a photostat of the pertinent pages of the inventor's notebook. Copies should be routed to the research director (in duplicate, so that he may mark one up and return it to the patent department, as he will probably wish to do), and to the committee; other copies will be retained by the patent department and the inventor.

It will be observed that in the preparation of the "report of results" the inventor has been closely associated with the research department, but that in preparing the "statement of invention" he has been associated more closely with the patent department. This affords somewhat of a cross-check on what he claims, gives the patent department a more independent view in appraising the record of invention at the outset, and allows for the fact that when the next step, the drawing of the application is reached, the whole matter will pass under primary control of the patent department.

It is wisest to leave drafting the application, since it is a specialized art, to the patent department's preferences, subject to two considerations. First, the patent department should have complete liberty to call on the research department for technical or scientific help in preparing it. Such assistance will usually take the form of consultations to explain the invention and suggest, modify, or reject claims; on occasion it may run to experiments or models to demonstrate operability or differentiation from the prior art. Second, the completed draft of the application should be reviewed by the committee. Such co-operation accomplishes the double purpose of producing an application soundly grounded in the technical art and designed to carry through the company's general patent policy as thoroughly as possible.

Several references have been made to the research worker's notebook. From the patent point of view, the notebook is the most important document in the chain of invention papers. Its function is to record in chronological order, clearly and understandably, just what is done day by day, what the results are, and when they took place. It usually is a somewhat slipshod affair. If half the time, energy, and ingenuity that are devoted to devising elaborate methods of proving the date of conceiving an invention were, instead, expended in everlastingly drilling research workers in keeping better notebooks, not only would such dates be proven more easily, but the whole question of conception and reduction to practice would be answered in understandable fashion. It is to be hoped that more of our technical schools will give curricular attention to this, for it enters into the validity of a research program quite as much as it affects patentability.

There have been a number of excellent articles on notebook form and method.[1] While they all express certain personal preferences, there are a number of fairly common elements: (1) the use of a bound notebook with all pages used consecutively; (2) entries made currently in ink, each page being dated and signed; (3) witnessing and dating of each page by a person competent to understand the entries (if the research director does this, it will be of mutual benefit); and (4) a record presented in such form that it needs little explaining. This last means not only that quantities, conditions, methods, results, and efficiency shall be fully stated, but that no terms or abbreviations capable of being misinterpreted shall be used. A notebook marked by erasures, having items that have to be explained away, or written up in errorless perfection from rough working notes is eminently productive of trouble. Most research workers will not be convinced of this until they have had the pleasure of being subjected to savage cross-examination in a bitterly contested infringement suit before a skeptical judge.

Each research worker's notebook might well be reviewed at periodic intervals by the patent department to see whether something patentable, but undetected as such, can be caught.

Patent Prosecution and Litigation

The natural sequel to filing a patent application is conflict with outside agencies: in order of frequency, with the Examiner and his citations of prior art or other Patent Office actions, with another applicant in an interference, or with an infringer or a patent-holder charging infringement. In all of these eventualities, two types of questions arise: those most closely connected with scientific or technical problems, and those relating to or affecting the company's patent policy. The most that can be said of the first type is that it calls for the fullest co-operation between the inventor, with the help of the research director, and the patent department. As an example, consider the inevitable problem of citations of prior art. Most persons at all familiar with patent work are a little too apt to feel that an Examiner's sole purpose in life is to prevent any patents from being issued. A little consideration of the fact that a very large number of patent applications are filed for improvements, a fact necessarily connoting an important mass of prior art, should dispel this idea. The technical man, grounded in why he was trying to do what he claims to have done, is in a much better position than any but the most gifted of patent lawyers to point out its distinctive novelty and utility.

With this type of problem, we may contrast a requirement for division of an application. There the primary consideration is often whether the second or related invention is worth covering, what position the additional patent would occupy in the company's patent structure, whether it is protection for production, trading material for a deal with competitor holding a needed process, or likely to wind up as only a neatly sealed and technically interesting document. This is beginning to be material for the committee. The interference is even further their material, and with the infringement suit, of course, there is no doubt.

Even the most occasional filing of patent applications is bound to produce a welter of such matters. The proper clearing house for them is the research director, since he is responsible for the quality of the scientific and technical collaboration his staff can give the patent department, and intimately concerned with what protection their work will get and can contribute to the company's business. It is advisable therefore that all patent matters be brought to the attention of the research director or department. In some organizations, this may be difficult, for the patent department may be an arm of the legal department (which is rather commonly directly responsible to the president); it may be so large or so competent as to feel that it is fully co-ordinate to the research department; or its volume of work may be extremely large. On examination, most of these objections fall before the simple observation that the research director is the man who must make the research program function, and that patents, by any measurement, are certain in the minds of some company officials to be the index of its success or failure. If this view is taken, the research director will decide what goes to the research worker, what goes to the committee, and what to both. As an exception to this rule, it is probably better for infringement matters to be routed by the legal department, whether originating there or sent in to it by the patent department, directly to the committee, with notice to the research director. The reason is that in infringement matters, the effect on company patent policy is the fundamental problem.

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1. Hollabaugh, C. B. "Protection of the Results of Chemical Research." *J. Chem. Education*, **21**, no. 7, 321–325 (July 1944).
2. Sinclair and Carroll Co., Inc. *v.* Interchemical Corp. 65 Sup. Ct. 1143 (1945).

CHAPTER XXIV

Licenses, Royalties, and Patent Pools

Licenses and Royalties

Much of the factual commercial usefulness of patents lies in the power to transfer or divide the legal rights which they create, and to shape and direct the manner in which those rights are used. Sooner or later, every company is faced with the problem of securing the use of patents held by an individual or a competitor, or is asked by another company for a license under its own patents. This, of course, is only one phase of the whole question of intercorporate co-operation in research and development—a question involving such diverse considerations as the wisdom of free interchange of laboratory information,* and the effect on a company's reputation of well-founded or groundless charges of antitrust activities.†

Patent Rights Must Be Transferable

A patent that could not be transferred or licensed would be virtually valueless to most inventors. It would lie idle in the hands of the inventor unless he had or could enlist about him the capital, the production knowledge and plant, and the sales and promotion personnel and techniques required to put the invention on the market in all or even a majority of its field of important application. Unless the commercial exploitation of innovations is to be handed over entirely to companies that are so well established that they can count on meeting competition by excellence of product, low prices, and thorough selling, the patent is the central mechanism on which the

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This chapter by Albert S. Davis, Jr., Resident Attorney, Research Corp., who acknowledges the review of various portions of the material and valuable suggestions as to the content by Carl W. Hedberg and Robert R. Williams of Research Corp. and Harold T. Stowell of the Washington, D. C., bar.

* See Chapter 27.

† See Chapter 25.

manufacturer will rely. Unless the patent right can be effectually transferred in its entirety, it is likely to be useless.

Since the monopoly granted by a patent is as wide as the art that its claims cover, and extends over the entire country, means must also be devised to permit the transfer of *part* of the functional and geographical scope of the right to exclude others from using the protected invention.

Let us assume, for instance, that a small company is organized around a patent covering a process for chemical separation of proteins from raw materials. Its promotion and sales personnel are thoroughly experienced in the New England and Middle Atlantic states. It does not have the plant, men, or money either to sell or distribute to, or produce for, the remainder of the country. The value of the invention is fairly measured by its natural country-wide future market. It is natural to provide territorial licenses to permit other companies to serve the public in those areas, and obviously necessary to provide that the licensees are each to enjoy a monopoly within their own territories so that each may develop its new business and none will commence a commercial attack on the patent owner. If the company owning this patent decides that the job it can do best with the process is to produce and market high-cost pharmaceuticals, that it should license one or more bulk chemical producers to use the process for other purposes, and that it does not intend to allow such licensees to destroy its pharmaceutical business; the logic behind such a decision is apparent.

The License and Its Problems

For the moment, let us consider the problems arising from a request for a license or the need of one. The executive of the future licensor will first appraise the tactical situation, and his thoughts might possibly run:

> Why do they want to practice this invention? If it is to compete with our own line of business, nothing doing, unless I can (*a*) trade something we need in return, or (*b*) put on a high enough royalty so that we will still have a price advantage, taking into account any possible economies of production in their factory, or (*c*) we need the royalty money badly, or (*d*) I can get a gentlemen's agreement to give us a license on something we may really need in the future. If it is to make something we don't make but might make at some time in the future, can I set the royalty high enough to give us a price break if we ever go into the field? Or should I try to sell them a revocable

> license, or one where the royalty goes up when we enter the field? What can I get in the way of an agreement to give us back licenses under improvement patents, or statements of know-how? If it's something we will probably never get into, how much money can we get out of it, not necessarily through a high royalty rate, but through encouraging full production? How should we restrict the license so that the licensee won't get into our hair? Are they nice people to do business with, or will we have to watch them?

Much of this train of thought will be so automatic as to be almost unsensed; some of the points will be carefully considered. In reality, it boils down to two points: the effect of the license on the licensor's own business, and the financial angles. There is nothing in law or equity that calls on a patent-holder to injure or destroy itself to the end that its competitors may lead an easier and more profitable life. On the other hand, co-operation usually breeds co-operation, and the general history of intercorporate patent licensing in this country is, with a few notable exceptions, a curiously unselfish one. Most small companies will rarely license their basic patents.[10] Aside from such obvious limitations, however, we find that typical practice is to grant licenses rather readily.

> While the patent law permits the patent owner to "enjoy the exclusive benefits of his invention"—i.e., to use it or not use it as he may see fit and to restrain all others from using it during the period of his monopoly—the chemical industry has not made much use of this privilege. In cases where patents have been sued upon in the courts and enforced, the usual result has been that the erstwhile defendant has paid damages for past infringement and has purchased a license on such terms that it has continued the business at a profit. Few if any patent-holders, particularly the large companies, have flatly refused to license competitors. (One of the largest manufacturers reports after a careful survey of the last ten years: 1,015 requests for licenses; 1,000 licenses granted, 15 refusals.) Most of the companies seem content to profit from the invention mainly through the medium of having been the first to introduce it, and royalties, when received, serve to repay research costs and provide only a minor contribution to general profit schedules.[5]

Royalty Computations

The financial side of the problem will probably take one of two aspects, the making of money or the careful adjustment of a royalty as an economic load to be carried in the competitive race. Calculation of royalties for income purposes depends on increases in sales, cuts in production costs, or other factors increasing profits. With a product patent, this means prediction of the market (with due regard for length, cost, and success of introductory campaigns), determination of a competitive price, and dissection out of a permissible share of the profit. With a process or production machinery patent, one considers the saving which can be made, and the wider market possibly available for cheaper, better, or more uniform products.[4]

The individual inventor who lives by royalties will usually try to get what the traffic will bear. In the case of one company charging royalties to another, however, it is doubtful whether royalties will or can ordinarily be a major factor in income. One reason for this is that the licensee under one patent may very well be the licensor under another. A second reason is that a feeling of paying undue tribute is a violent stimulus to competitive research in a field to which the licensee company might otherwise not apply itself.

Where royalties are intended to affect competitive positions, a much nicer calculation is necessary, for the effect on price is all important. The licensing company will project itself into the would-be licenseee's mind as far as possible, seeking to determine with some exactness the all-important figure of production cost without royalty, and the loads that it can reasonably expect to be placed on this cost for overhead and profit. It will then attempt to adjust the royalty to the point where the licensee must operate marginally if it attempts to undersell the licensor. If the process or product is one with which the licensor itself has had experience, or which it has actively considered for production, the figuring out of the licensee's cost pattern will be much easier. The usual method of approach under such circumstances is to set up the licensor's own cost sheet and load figures as working papers, and attempt to pare them down to a little below the point where the business could be carried on with a reasonable margin of safety. This paring operation depends very largely on the type of process or product involved, but will usually include assuming maximum labor efficiency and yields, reducing any internal shop and production overhead and management loads very sharply, and holding promotion, sales, and distribution costs to a minmum.

Any unusual labor-market benefits, transportation differentials, low selling and distribution costs, or advantages of an established market list which the competitor enjoys will also form part of the complete picture. It is occasionally instructive to examine the published balance sheets of the licensee to attempt to determine the loads which are actually being used. One extremely important source of information, sometimes neglected, is to compare prices and assumed cost and profit factors in existing competitive items not involving the patent. Unless there is an undue disparity between the general character of the items on which there is existing competition and the patented invention, the figures on the former are likely to be quite helpful. With well-established firms, of course, the sales department usually will already have a pretty fair line of information.

In actual practice, most licenses, even to a competitor, carry royaties that are set more or less by rule of the thumb, and without any such tactical jockeying. In many cases, it is felt that the work involved is too great or too unreliable for any competitive advantage which could be obtained. Some licensors simply take the bull by the horns, and provide that their licensees' prices are to be thus and so, assuming that they themselves are engaged in production under the same patent. In other cases—for instance, with one patent-holding company which is highly interested in medium-priced and higher-priced pharmaceuticals—a practice has grown up of setting almost all royalties at from 5 to 7½ per cent of price. Where a company's royalty habits have given satisfaction in the past, there would seem to be little reason for altering them. When the sales department complains of undue difficulties in selling a company-originated item against a licensee, however, or where a licensor's sales as adjusted to general market conditions and any advertising peculiarities, have been standing still or falling off, and a licensee's sales, adjusted in like fashion, have increased markedly, it is suggested that when negotiations next commence there be a thorough study of the probable impact of the royalty on the licensee's price line.

License Techniques

In the last decade probably no aspect of patents has brought about such vituperative discussion as the licensing mechanisms which have grown up about almost all patent structures. The peculiar legal obsolescence surrounding such structures is not difficult to understand, for a patent is not only one of the few remaining lawful monopolies in a prevailing politico-economic phase of society which condemns all monopolies except those of the state, but it also was a tool admirably fit for building industrial monopolies or restraining trade.

It is obvious that in the adaptation of a patent's monopoly to industrial use or the use of a patent as a competitive device, it is frequently desirable or necessary to stipulate that the company or person using it is permitted to do only certain things under it, or must bear a certain load. It is equally obvious that, by the planned or forced bringing together of patents and portions of patents, there may be created an industrial monopoly bearing some sort of rough relation in power to the scope of the assembled patents. This relation is not an exact one, for many, if not most, patents are only indicators of what commercial practice will be, and the most valuable patent is useless for anything except suppression of others unless adequate know-how can put it to work.

When a license is given or taken as a purely competitive device, the importance of the restrictive angle is evident. This same theory of restriction is at the heart of the process of controlling competitive ability by a calculated adjustment of royalty. Even when a license is granted so that the patented article may be merchandised for the licensor, or so that the licensee can complete a minor step in his path of lawful ability to produce, or so that the patent owner can derive revenue from the licensee, there is the same pervading idea of a legal restriction which has been lifted in part.

Since every patent is a monopoly, every transaction relating to the use of patents—enforcement, assignment, licensing (whether primarily restrictive or primarily nonrestrictive), the charging of a royalty, gathering the right to use or actually using two or more related patents, even the non-use of a patent—is one which to some extent deals in monopoly. A patent, and its legal results, are a constant challenge to the doctrine that "I'm as good as you are." Bearing this in mind, it is easy to understand the celerity with which criticism of the most innocuous patent transactions arises.

Unfortunately for business planning, this criticism is badly organized and poorly disclosed. The executive planning a patent transaction which is openly characterized by strong restrictions or by a good chance of large-scale industrial success will usually have in mind that he may expect criticism if his plans work. When he asks what the chances of trouble might be, his counsel will render an opinion. Admittedly, an opinion carries no guarantee, an exasperating factor to men accustomed to deal in precise things and predictable reactions.

By the very nature of the manner in which our antitrust laws are motivated, made, enforced, interpreted, and planned against, however, this is only natural. Department of Justice press releases, the trend of consent decrees, congressional and investigatory reports (which are not always written for openly evident reasons), and even the private writings of officials are of equal importance with the recognized authority of judicial decisions. The complex result, moreover, is never in a static condition. As long as the large-scale assertion of business domination and its repression by the government continue to be cyclical in their manifestations (and that will be as long as personal ambition itself persists), legal mechanisms will temporarily outstrip governmental controls and will in turn be overtaken. It may also be fairly expected that the certainty and intensity of criticism will be in direct proportion to the success of the assembled patent structure or of the transfer of the patent or the patent right.

> When a situation like this develops, a discussion of early decisions serves no purpose other than to depict past history. History is interesting, but when its teachings and precedents have been discarded it is not particularly helpful to the practitioner who has to advise his clients as to how the court will probably act next year.
>
> In this, as in many other phases of the law, when the fundamental principle first came up for decision, all of its possible applications were not explored and considered. In the particular circumstances of the case under consideration the application of the principle may have been innocuous enough. In the next case, the principle is applied to a different set of facts, where the equities may not be so strongly in favor of the plaintiff. Finally it becomes apparent that, while the application of the principle may be equitable in some cases, in general, it leads to inequitable rights. When that happens the old precedents are abandoned and the Supreme Court lays down new principles and new standards to govern future practices.[6]

While the detailed prediction of probable legal results of a given course of action is a matter for company's counsel, the executive will be in a much better position to formulate the line along which he wishes to move if he knows something of the legal-economic philosophy inherent in such situations. Speaking very broadly, one good rule is to urge the case against too much reliance on technical devices to defeat the spirit of the law.

What is this philosophy which he faces? Whether it will change in the future, in direction or application, is a matter of speculation. Assistant Attorney-General Berge spoke of it recently as follows:

> We do not challenge for a moment the fundamental concept of the patent laws. We must have patents. And we must have legal protection for inventors and those who purchase the rights of inventors, so that they have a very limited monopoly for a limited period of the product or process.
>
> But when you use that patent to control the whole business—when you use it as a weapon to acquire monopoly control in an industry—then it becomes an entirely different matter.
>
> The purpose of the patent system, as stated in the Constitution and in the law itself, is to promote science and the useful arts. And the trouble is that it has been used to restrict science and the useful arts through the manipulations and monopolistic devices that have been developed. I think our problem is to operate on them.[3]

This text requires a considerable gloss. First of all, what is a monopoly? In essence, it is the control of an industry. Assuming that we define control of an industry as being domination of 60 per cent or upward of it, we begin to wonder what an "industry" is—a point insufficiently explored by the courts or antitrust defendants. It may well be argued that when there is a country-wide domination of a process or product having major industrial importance but when there is also an adequate substitute process or product, no monopoly exists in fact, even though competitors have seen fit to pay royalties to the dominating company rather than use the substitute. Under the stress of war the development of a tendency to overdignify patent control against which substitutes might be available, by using the term "bottleneck" or "key position," is an indirect confession of this.

The net result of this philosophical combat is that at some point all monopolies having a planned destructive effect on industry reveal their own culpability, because they succeed.

Antitrust troubles arising out of patent transactions, however, will almost invariably include an assertion of monopoly only as incidental color for a charge of specific "acts in restraint of trade." One reason is that proof and persuasion of the court are here much easier. Another is that by destruction of trade practices held to be illegal, and by denying to patent-holders the right to enforce their patents by infringement actions, a long step can be taken to destroy the monopoly created or characterized by the practices.

It is impossible in the scope of this chapter to analyze or even to enumerate the patent practices which have been the subject of adverse judicial action in the name of the antitrust laws. Generally speaking, they are characterized by:

> (1) An attempt to make a group of patents (much more rarely, a single patent) the means of an *industrial* monopoly the scope and effect of which are greater than the patents, by their existence or by contracts which pass beyond what is contained in the patents themselves.
>
> (2) An attempt to control prices other than those on the first sale by a licensee competing with a manufacturing licensor.
>
> (3) An attempt to suppress competition in geographical or technological areas through licensing although no patents control the real subject matter of the agreement.
>
> (4) An attempt to sell or prevent the sale of unpatented materials through the use of patents on other materials or processes.

It will be appreciated that these are purely illustrative. For a view of the contrasting philosophies, the reader is referred to references 1, 2, 7, 8, 9 and 11.

Patent Pools

A patent pool may be roughly defined as a group of patents in a fairly integrated field, assembled by their various owners so that they may be licensed out, for control, for revenue, or to enable the members to practice the whole art. A patent pool will always be roughly discussed in terms of monopoly and antitrust. There is nothing inherently vicious in such a device. The fact that any successful business with a patent structure of its own eventually runs into some other business with a dominated, dominating, useful, or competitive patent structure of its own, has been a phenomenon of industrial organization since the first major interest of corporate enterprise in patents. One of the oldest patent pools is that of the sewing machine which dates to about 1850.

Most patent pools are formed because of one of three motivations. We have referred before to the line of thought followed by the executive who is attempting to determine whether or not to grant a license, and the terms which it would impose. Where two companies respect each other as competitors, and their work lies along sufficiently similar lines, they will usually find that their improvement patents result in a continual interchange of attempts to get slightly ahead, protected by minor improvement patents. In the interest of ending continual trading of rights back and forth, they sometimes arrive at the conclusion that an arrangement providing for automatic interchange of improvements as they appear is the easiest practical way to obviate a useless waste of time and bickering over *minutiae.*

Again, since our major research laboratories stand side by side on about the same level of basic knowledge, it is usually true that they tend to break through their ignorance of the new at about the same time—a condition which is productive of multiple interferences, and which creates small blocks of patent protection, no one of which is useful without the others. The nation-wide research in radar during World War II is an outstanding example of this. Under such conditions companies engaged in the same line of work find it necessary to assure themselves in advance of the ability to use what may come out of all their laboratories.

Finally, of course, situations have arisen where groups of companies have set out with the deliberate purpose of dominating a sector of industry, and have hit upon the assembling and cross-licensing of patents within their groups as a means of freezing out competition and assuring their ruling position.

If the only purpose of a patent pool is to render inventions available to its members (that is, if there is no monopolistic intent), no criticism can fairly be directed at it, until it becomes in fact a monopoly. Such a pool would be characterized by a membership open to the trade at large and a contract granting a license at reasonable royalties under the patents of all members. The royalties would be divided between the administration of the pool (expenses, acquisition of patents, and possibly research fund) and the various members, in some sort of ratio to the cost of development and patent expenses, the technological value of the patents contributed by the particular company, or the like.

Imagine, on the other hand, a pool created by three members of an industry. Assume further that it refuses to admit competitors, that it follows an aggressive course of acquiring patents, some of which it does not work though they could be of vital importance to outsiders, and that its members agree among themselves to follow certain price lines, to incorporate certain patented structures which will have the effect of establishing price lines, to limit their production, to use only devices which will wear out unnecessarily soon, or not to compete with each other in certain areas or certain lines. It is equally obvious that judicial criticism of this position may be expected. The important thing is that the criticism should not be directed at the patents (save as they are, by contract, made tools of the monopoly) but at the methods and motivations of use.

The basis for criticism is that the monopoly inherent in the patents or in a combination of patents has been deliberately enlarged, and that by agreement the members of the pool have shown that their interest does not lie in making patents useful, but in monopolizing the market in their industry and suppressing competition by joint action. It is precisely this type of situation which has been so much stressed by the numerous investigations of the last decade.

If the executive feels that he needs a patent pool, it would be well for him to ask himself if he needs it because its existence will make it easier for his company to produce better products at higher total profits. If he can answer this question with a "Yes," and will plan his agreement accordingly, he will have a pretty good chance of averting trouble.

The Utility of Patent Pools

What are the hallmarks of a useful patent pool?

First, it should, if at all possible, be open to all comers. The lawyer will argue for this, since it avoids any charge that insiders are trying to corner the market. The executive may well keep in mind that a disliked, would-be pool member may suddenly turn up with something he needs to have—particularly in these days when company research in basic and even in applied fields may run far afield from logical lines of commercial specialization.

Secondly, no attempt should be made to freeze the patent structure within the group. This is not quite the converse of what has just been said. In any complicated patent structure, there will be a large number of patents which are not worked because they do not fall within the immediate interest of their owners, because they are not profitably usable in certain preferred lines of work, or for other reasons having nothing to do with "shelving." It will pay dividends in public relations if such patents are made available to nonmembers of the pool who need them for their own purposes.

Thirdly, under no circumstances should the members of the pool parcel out certain fields of work or certain areas of production and sale among themselves. There is nothing in the law which compels a company to sell where, without agreement, it has never seen fit to compete in the past; but once such a disinclination is crystallized into a ban, trouble can be expected every time. A manufacturer of sheet plastics can choose of his own accord not to mold toys, but it would be foolish of him to agree not to do so.

Fourth, there should be no attempt to place the management of the patents in the hands of one member, or in the hands of an unchanging group of members. Every man has his own particular specialties and preferences, and they will inevitably come out in the decision on what patent should be accepted, what patent should be pushed, or what patent should be given a high technological valuation for royalty purposes. This leads not only to ill-will within the pool, but upon occasion to charges that the managers of the pool are favoring their own companies with the deliberate intention of harming others.

Fifth, the royalty structure, if royalties are to be charged, should be conceived in a sense of "what the traffic can bear." The fairest system, and the one least conducive of criticism, is that based on a percentage of sales or production value, for the use of a patent is a good indicator of its value to the licensee. Frequently, of course, it may be necessary to take into consideration that a patent which is vital to one user may have only a nuisance value to another, or that one user is engaged in producing high-cost, high-priced items while another is engaged in bulk low-price manufacture. The system most likely to lead to criticism, unless all members of the pool are on a fairly level economic footing, is one which charges a set sum for membership. Upon occasion, pool members may see fit to abandon royalties altogether, as unrelated to the primary purpose of their pool, to get the right to produce without interference.

Sixth, there is a good deal to be said for having each member of the pool prosecute its own patents, rather than have the pool itself attempt to do so through some central agency. This avoids the difficulty of having interfering applications in the same hands, and prevents the creation of a department which takes out patents automatically, despite their value, because it is its job to take out patents. Since there is a distinct possibility that what is of no interest to an originating member may be of great value to another, however, it is wise to establish a system by which a company will advise the pool of what it considers to be patentable invention, and by which it will give other members the right to decide whether the pool should have the benefit of a patent covering an invention upon which the originating company would not file.

Finally, the members of the pool should operate it on the principle that it has been created to make patents available for use, not as a means of suppressing competition.

In the past the government has seen fit to sponsor certain patent pools, with the purpose in mind of making all of an art widely available to companies which could not operate effectively without all of the art. The catalytic refining and rubber pools set up during World War II at the insistence and under the direction of the government mark a noteworthy trend in this recognition of a sound principle. It is to be hoped that it may be continued in the future.

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CHAPTER XXV

Relations with the Public and Governmen

Relations with the General Public

Every company and every department of a company have som relations with the public. Therefore, no department, no compan or any industry has the choice of adopting or not adopting a publ relations program. The day a company or industry starts busines it starts having and creating public relations, with each departme or segment of that enterprise becoming a functional factor in r solving the problem of public relations.

But each industry, or company, or department of a company h a choice to make about the state of its public relations. Indust and its component parts can achieve considerable control over t character of these relations and it is of prime importance to the co tinued success of an industry and its component parts that its publ relations be favorable.

Many companies are great companies in the public mind becaus consciously or unconsciously, the men who represented them in t past, and those who represent them now, have personified their co panies to the public by themselves possessing qualities that win a miration and respect from American men and women.

Most of the men whose acts resulted in these high opinions we not "public relations men" in the sense that they headed public r lations activities; they were public relations men in the sense th they directed company action with an *understanding* of the publ interest and the public point of view.

Good public relations do not just happen; nor will talking abo them, or putting out a house organ and a series of newspaper r leases, dispose of the problem. Companies—and their compone

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This chapter by J. H. Schaefer, Vice President in Charge of Manufacturing, Et Corp.

parts—which strive to achieve good public relations are more likely to succeed if they work according to a plan, and if one competent person is charged with the responsibility of making the plan effective.

The entire task of maintaining good public relations cannot be delegated successfully to a department any more than industrial relations or accident prevention can be made successfully the responsibility of only one person or only one department. But it helps in any activity to have some one person designated as "responsible."

Public Relations—What It Means

The term "public relations" has been used for such broad and diverse purposes that it is well to define the expression as it is used here. First of all, this chapter is concerned not with the broad concepts of public relations, but with only those phases of the art or philosophy which relate to the effectiveness of industrial research. Just as research is a broader term than industrial research, so public relations for industry has a broader meaning than public relations for industrial research.

For the purpose of these chapters, *public relations means creating and maintaining in the minds of certain groups of the public an understanding and an appreciation of how an industrial research organization works to aid the material welfare of humanity.* More specifically, the related groups (among whom a positive opinion should be maintained regarding the significance and implications of the industrial research organization) are employees, community leaders, labor leaders, university faculties and students, government legislators and representatives, and public opinion leaders.

The public relations of industrial research encompass the composite of all personal relations between those engaged in industrial research and those whom they influence. Hence, while an organized program is recommended, this does not lessen the individual responsibilities of all those engaged in industrial research.

To accomplish understanding, a public relations program may make use of such tools as advertising, booklets, speeches and lectures, many types of written articles, motion pictures, and still pictures. These media of thought transmission must be employed so that they *influence the thoughts* of those people whose opinions affect industrial research and *must not remain merely words, or sounds, or pictures.*

The cost of expert guidance in public relations, as in many other fields, is likely to be less than the cost of wastage involved in ineffective work.

A public fully informed about the operations of an industry, a company, or an industrial research department can be expected to acquire sound and fair attitudes and opinions. In the long run, the general public, when fully informed, is fair in its judgments and conservative in its attitudes.

The first principle of sound public relations is conduct worthy of public favor. The second principle is honesty and sincerity in any phase of that conduct.

An "Open Door" Policy

A major criticism of research men by public relations experts has been their tendency to appear cloistered, to seem to work in an ivory tower. Industrial research men have exaggerated the secrets and neglected to emphasize the common sense of scientific laboratories. People, your public, maintain a respectful, though skeptical, attitude toward this mysterious side of business activity.

Research management has been warned repeatedly about the disadvantages of such a policy. Charles F. Kettering said: "When you lock the laboratory door, you lock out more than you lock in." The late Thomas Midgley, Jr., in one of his last public addresses, said:

> Many of the difficulties that have been placed in the way of industrial research resulted from an ignorance on the part of the public and even of men in high places as to what it was all about. Ignorance breeds fear and fear motivates destruction. I am advocating that industrial research itself improve its public acceptance—not that industrial units merely advertise their own research departments. In fact, this latter activity may be deleterious to the desired effect. Advertising copy has a way of romanticizing research, putting an air of mystery around the laboratory. . . .
>
> The public should be told just what research is when used by industry and how it benefits mankind.

Public Opinion of Industry

Nearly every industrial research laboratory has an opportunity to help create and maintain good public relations for itself, its parent company, and for American industry. The accomplishments of industrial research are tangible gains to society. Whatever success is achieved in the field of favorable public relations for industrial research will increase public appreciation for industry as a whole.

Obviously, the creation and maintenance of good public relations is not a problem peculiar to industrial research. The particular principles that apply to industrial research apply to any other activity that has for its ultimate objective an improvement in economic development and human welfare.

Individual Responsibility

Everyone who expects industrial research to be his career, to furnish him his daily bread, is under obligation not only to his profession and his employer, but also to society, to do his part in translating to those with whom he comes in contact a concept of the industrial research contribution. Public relations, therefore, enter daily and personally into the lives of all industrial research workers. These fundamental truths can be applied to questions of national and international scope.

The most logical advocates of industrial research may be expected to be found among those who know its processes best. If they do not defend it and believe that, in the long run, it serves mankind well, then industrial research is not an institution which should survive or be expected to.

Broad Programs of Associations and General Industry

Abraham Lincoln once said: "Public sentiment is everything, with public sentiment nothing can fail. Without it, nothing can succeed. Consequently, he who holds public sentiment goes deeper than he who enacts statutes or pronounces decisions. He makes statutes and decisions possible or impossible to be executed."

This is a guiding principle underlying the modern philosophy of public relations. The necessary complement to the above principle is that *only* those private interests which are in harmony with the public interest can be a basis for sound public relations. All public relations programs of industry in general, and industrial research groups in particular, must be geared to these principles.

Development of a basic public relations program for industrial research is the function of an association representing large segments of industry or of industrial research. The job of educating the gen-

eral public on the broad benefits of research work is a long and diff
cult task and belongs rightly to the collective group or associatio
Upon the individual units devolves the responsibility for their sp
cific organization and for their publics: employees, local communit
customers, stockholders, and appropriate government agencies.

Present Opportunity

The general public has been made acutely aware of the impo
tance of industrial research as a result of the contributions of indu
try to warfare. The story behind the atomic bomb has reached th
minds of a large percentage of all literate Americans. Other widel
publicized developments such as the sulfa drugs, penicillin, syntheti
rubber, and high-octane gasoline have been dramatized by new
papers, magazines, radio, and motion pictures. These provide a
excellent foundation for a concerted effort to educate the public t
the true meaning and value of industrial research to society. Als
any effort to gain public interest and favor for any one segment
industrial research will be more likely to succeed now than at an
previous time.

Successful Methods of Influencing Public Opinion

Preliminary requirements for a successful program might i
clude: (1) an earnest and sincere desire on the part of the organ
zation to seek good public relations; (2) a willingness to chang
policies and procedures in order to improve the contribution
the organization to society; (3) a willingness to spend effort an
money to remove causes of ill-will and misunderstanding betwee
the organization and its public; (4) a determination to create an
maintain within the organization a sound basis for good publi
relations.

Diagnosis of the factors affecting opinions and an analysis
the opinions which have resulted from past conditions and even
are often prerequisites to a successful program. Accurate measur
ments of opinion are available through modern methods of samplin
representative groups. Use of such techniques in diagnosis requir
rigid controls and expert management to insure accuracy. Of pr
mary importance is the elimination of conditions that create publi
resentment, suspicion, or misunderstanding.

Adoption of a policy and a definite program for improving pu lic relations is characteristic of those organizations which have been successful in influencing public opinion. The following procedure for industrial research organizations, collectively or individually, is suggested for consideration:

(1) *Direction.* Leadership of a public relations program should be delegated to one person. He should be able in understanding human relations and skilled in influencing people. He should have a knowledge of the media to be used to reach the desired audiences and the ability to write or express ideas clearly and convincingly. In an individual company, he should be an executive officer or an assistant directly responsible to the president. In the research department of a large company which has an established department of public relations, there are two practices that have been successful: a trained member of the public relations department may be assigned to the industrial research department, or the head of research or his assistant may serve as liaison officer regarding all plans for public relations for industrial research.

In an association, a committee chairman, with a representative committee and an appropriate staff, usually directs the public relations program. Many organizations employ public relations counsel, or use public relations facilities provided by an association.

The employment of talent, however expert in public relations technique, is not a substitute for the participation of management in a public relations program.

(2) *Adopting a Policy.* A basic, yet flexible, policy for public relations should be defined. As far as possible, *all* management policies and action should be carried out in a manner that deserves public approval.

The employee relations program, whether it is managed as a separate activity or not, should be considered an essential basis for improving public relations.

Organizational methods and procedures should be so designed that they conform to public relations policies. Ideas that are not generally accepted by the public may become so after they are shown to be of value and interest to them.

Every public relations policy, no matter what phase of the program it is to govern, should be formulated and carried out in relation to its possible effect on *all* of the organization's various publics. The policy should be such that the program may be based on normal day-to-day relationships and not depend wholly on special even or occasions.

(3) *Planning the Program.* Starting a public relations progra with only the general objective of improving opinions and relation is likely to be both ineffective and wasteful. Specific planning t reach measurable and attainable objectives is advisable. In mos cases such a plan will reveal that major attention should be devote to specific publics: employees, communities, stockholders, opinio leaders, government agencies, educators, etc.; but each of these pub lics is a part of the general public and moreover is an excellent gat way to that general public. The total opinion of the public shoul be considered in planning the program.

Public Relations Tools

Any method of influencing or changing opinion may be consid ered as an instrument or tool for a public relations program. I large programs, some of these tools may be very elaborate, as, fo instance, the "Parade of Progress" staged by the General Motor Corporation as a part of its public relations program. A carava of traveling exhibits moving from town to town took the Genera Motors message of progress through industrial research directly t the general public.

Such specialized programs are beyond the scope of this discu sion, since able public relations managers would logically be place in charge of programs involving large expenditures and would pla for the use of those tools most likely to reach the desired objective at moderate cost.

The most effective uses of the more usual public relations too have been developed during recent years to high degrees of craft manship. Experts in the various media of communication ar available and numerous textbooks have been written on the subjec which follow. Only the briefest references and fundamentals ar presented here by way of illustration.

Employees as Public Relations Ambassadors

Employees are effective ambassadors to the public. If well in formed, they will refute misstatements and distortions of fact.

The concept of an employee as a member of the general publi whose good will, like that of the company's best customer, is courte through the media of information, is relatively new. It follows logically the recognition of stockholders and the general public as entities desiring, and entitled to have, current and accurate information concerning the operation of a business.

Repeated instances have shown that employees as a group are eager for "the inside story" of industrial and company economics and receptive to it, assuming simple, understandable presentation. Generally, too, employees are inclined to be favorably disposed toward the company for which they work. In the absence of accurate information, however, they frequently are influenced by misinformation.

This emphasis upon favorable relations with a company's employees does not mean, of course, that it is the responsibility of the research department to take the lead in creating good labor relations in other departments in a company. That is an over-all company responsibility and, quite properly, is usually designated as a joint function of the personnel or industrial relations and the public relations departments. It does imply, however, that the research laboratory should undertake a program of building the best possible employee relations within the laboratories and should instigate the use of public relations media in other departments designed to create in the minds of the employees of those departments the need and value of industrial research.

To an operator in manufacturing, a research worker often seems to be a "non-producer." The research worker may be receiving no more, or little more, salary than the producer-operator but he appears much better off. He may be "suspect" to the operator unless the industrial research laboratory is accepted as an essential and integral part of the company.

Employees in other departments also should be informed of what the work of research laboratories means to the average American in terms of new jobs and better products.

Brief publications about the technical findings, activities and facilities of the research department, prepared in laymen's language, and distributed periodically to a broad cross-section of the company personnel are helpful. Talks and technical movies presented before groups by members of the research staff, monthly abstracts of current technical literature distributed to certain people, and laboratory tours and exhibits for certain company employees are effective.

In addition to employees, all other groups with which an industrial research organization may be closely associated should be considered as gateways to the general public. A well-rounded publi relations program for an industrial research organization usually includes special efforts to improve relations with the community, wit the educational system, with government agencies and with othe firms in industry.

Newspapers

Newspapers are the traditional medium of publicity for an organization seeking to improve relations with specific communitie or with the general public. News releases are subject to such treatment as the reporter or editor believes they merit and may be considered worthy of very limited use or of no use whatever. If no properly presented to the newspaper, they may be rewritten or revised to such an extent that their original intent is obscured.

News, to be effective publicity, must stand on its own merit i honesty, proper presentation, and interest to the readers. Moreover, the company or organization which is as helpful, honest, an accurate in making bad news as readily available as good news i usually rewarded by the considerate treatment of both. Bad new almost inevitably becomes known to the press; it is best that it become known through company sources without second-hand exaggeration.

There are basic rules which should be followed in handling an release to the newspaper. Only when there is an important new story or an important personality involved should reporters be invited to a press conference.[1, 4] The most common method of presenting a story to a newspaper is to send a release by mail. Such " news release should never be longer than one and a half pages o typewritten copy, double spaced—unless it is considered of consummate news value to the public. Its value to the corporation issuin it is not the criterion," according to John Hill of Hill and Knowlton Newspaper editors are unanimous in saying that far too frequentl news releases are badly or carelessly written.

In general, there are two principal types of news releases. Th first is a statement or announcement regarding some event or in mediate development that is of general interest to the public. It concerns spot news and the need for a release often occurs unexpectedly. Simplicity and brevity in the written release are advisable, but successful public relations men often accompany the statement with an expression of willingness to amplify. The second general type of news release contains subject matter which possesses the element of news and, prior to its receipt, the newspaper editor may know nothing of the subject. Usually there is sufficient time to prepare such releases carefully. Often they are distributed to the paper a few days before the date of publication under an advance "release" date. To gain attention such releases must contain news that will command public interest.

Speeches

The personality and delivery of the speaker are often as important to success as the context and value of the speech itself. There are ample guides and pointers on public speaking in any library. It has often been said that a poor speech may be worse than none at all. A speech to be successful must first of all provide service to the *listeners.*

Booklets

The booklet or brochure gives an opportunity for pictorial as well as expository and descriptive writing. It provides a means for reaching a selected audience individually with a story of greater length than almost any other instrument of public relations.

Advertising

During the past few years there has been an increasing trend toward the use of advertising space for public relations messages, where formerly this method of reaching an audience was used almost exclusively for promoting the sale of a product.

Radio

News announcements may be included, if stated with sufficient brevity, in local or national radio news program. Special "sustaining" programs can be very helpful—the station at its own expense using interesting and appropriate comments provided by someone from the outside.

Forum Discussions

These occasionally provide an opportunity for a representative of industrial research to participate and thereby enable him to improve public opinion of his organization and of industrial research.

Motion Pictures

Motion pictures frequently are used for employee groups, customer groups, schools, or persons in allied trades, but they may be directed to the general public and distributed through film libraries.

Stockholder Reports

High on the list of subjects in which stockholders are interested is the research activity of their companies. Adequate and frequent inclusion of research prospects, facilities, and developments is advisable.

House Organs

Few organizations maintain house organs for the general public, but every reader of the usual employee, customer, or industry house organ is a part of the general public and also a powerful medium for reaching others. Reprints of articles in house organs are often useful for distributing to the general public.

Magazines

Magazines for the general public—such as *Reader's Digest* or the *Saturday Evening Post*—are available to a public relations program only when the message is one of unusual interest. An expert writer is usually required to interest the editor of such a magazine in the article. Material for an interesting article may, however, be brought to the attention of an editor, and if it is of sufficient interest, the magazine will assign a writer. Reprints or popular summaries of articles prepared for technical and professional journals may have considerable acceptance from selected members of the general public, particularly the "influence groups."

Open-House Days

In addition to employees' families and student groups, representatives of the general public are often included in "open-house" invitations. The public interest in industrial research laboratories is sufficient to attract opinion leaders in most communities.

Influence Groups

Teachers, ministers, editors, union leaders, chairmen of clubs, societies and civic organizations are in positions of leadership and, therefore, of great influence. Their opinions are spread and multiplied. Special material for these groups in the form of "information memos," "background material," "basic data sheets," "preview statements of intended action," etc., often yield large returns in moulding general public opinion.

Cost of Public Relations

Until recently, most men in industry questioned the value of dollars spent for public relations programs. In an attempt to dramatize the obligations of any business to the public welfare, and the accompanying importance of good public relations, some high-minded public relations men have placed profits second in the motives of business enterprise.

There is an insincere ring, however, to any public statement based on this misconception. Businesses are started and continued in order to make a profit. Without profits they will not long exist. Profit is the original and primary objective of a business enterprise, and there is nothing about this fact to hide or of which to be ashamed. The common error in public opinion is an exaggeration of the amount of profit business makes, and underestimation of the human values it creates. This error may be corrected by business without assuming the attitude that profits are undesirable. The profit motive may be explained as inseparable from human values—jobs, consumer benefits, and social progress.

The increasing demand that business accept substantial social responsibilities makes the success of any enterprise more and more dependent on meeting this public demand. On this basis, good public relations aid the creation and continuance of profits.

A Role for Management

Public relations must not be confused with the media which may be used to further its ends. Advertising, publicity, public speakers, motion pictures, house organs, etc., are *tools* which often are used to cultivate good public relations. They do not constitute public relations. Action or behavior is the root from which all good public relations stem. Interpretation or publicity is an essential subsequent step.

The essence of building good public relations is sincerity. Lacking sincerity, a public relations program is merely a veneer, frequently repudiated by company action. Actions should be such that the public can approve; only then can the tools of publicity be effectively used to create such an understanding that the public will approve.

Relations with the Community

Important segments of every company's public are the communities in which operations are conducted. Two groups are parts of each of these communities: company employees, who are also citizens living, working, and rearing their families in the community; and non-employee members of the community, including publishers, merchants, bankers, doctors, dentists, all other types of professional and business men and their families, municipal executives and officials, members of civic organizations. Both groups have an interest in the continuity of the company's operations in the community.[7] Radios, furniture, washing machines are bought; dentists' bills and doctors' bills are paid with the contents of pay envelopes. Any conditions that may increase or lessen the scope of the company's operations in the community or affect its continuity are matters of self-interest to *both* groups.

Co-operation with the Community

An important part of most sound public relations programs is to establish the laboratory or the company as an integral part of the community, identifying it and its personnel with community activities and, in turn, winning community favor for company practices, policies, and personnel.

Good relations between a company and its community stem, first of all, from good relations between a company and its employees. This concept deserves emphasis here because it points up another important phase of employee relations. To achieve employee aid in improving community relations, management and employees must clearly understand each other. Too often there are wide chasms between the "bosses" and the workers.

Employees as Ambassadors in the Community

A direct result of sound employee relations is a contented and efficient working force. An important indirect result is a staff of good will ambassadors in the community. According to C. S. Ching of the United States Rubber Company,

> The good will of the public secured through employees must be a by-product. If gotten as a by-product, it is much more valuable than anything gotten through strained efforts. . . . If you have personnel policies your employees believe in, if your employees believe in you, yours is an institution with character and integrity, that you are doing the best you can so far as they are concerned . . . then, without any advertising on your part . . . your employees begin to radiate your policies throughout . . . the community. Your reputation then begins to rise in the minds of the public, not because of a conscious effort on your part to bring it about, but through the influence of your employees.

Industrial research workers, in general, do not have many regular day-to-day contacts with the community. Their good will ambassadorship should be largely a by-product of employee programs. They should, however, be encouraged to take an active part in community affairs.

Since the public relations director, in a large company, may have to deal with more than one community, a resident assistant, or the designated public relations leader in the local research organization, may be needed to take charge of community relations. He should take an active part in community affairs and encourage other employees in such endeavors.

Community's Attitudes

Ideally, the first step in an organization's public relations with a community would be to find out what the community thinks about the organization. A survey conducted by means of a "Gallup" type of poll, and subsequently analyzed, may reveal a great deal about the community's attitude and provide clear goals as basic objectives for a public relations program. An individual company may not see fit to use such elaborate methods for sounding out public opinion. But anyone who earnestly seeks the truth can get a fair estimate of the opinion of a community toward a particular organization.

Good Housekeeping

The gradual elimination of any industrial nuisances—smokes, dusts, odors, unsightly "back yards," etc.—is one requisite for a program of improving community relations. Good housekeeping in the plant, neat buildings and grounds, help to create favorable impressions. Small plant models or photographs in association with products often can be exhibited in co-operation with local stores to tell the story of good housekeeping.

Open-House Tours

Open-house tours may help to make a good impression on the community in two ways. A clean, safe plant and laboratory inspire confidence and assist in attracting local personnel. A well-equipped, well-staffed laboratory can promote the idea of the benefits of industry and research to the community. The opening of a new laboratory or a new wing, or the installation of a new piece of important apparatus provides an opportunity for inviting selected groups to inspect the laboratory. A preview of new developments translated into practical things—such as houses, clothes, automobiles, gadgets, etc.—provides a publicity opportunity accompanying such a tour of new facilities.

Technological Assistance

Many opportunities will come to the members of an industrial research staff to present information to groups within a community, to co-operate in local community problems requiring technical, engineering, and scientific assistance, and to bring to the consciousness of the community's citizens the implications of industrial research as an interest of the community itself.

The services of the industrial research staff may be offered to civic societies, church groups, women's clubs, and any other groups in presenting programs with industrial research as a motif; technical services of the laboratory may be offered for projects in the community when such technical assistance is appropriate.

Relations with the Local College

If there is a college or university in the vicinity of the community it is taken for granted that a close relationship will be established between the faculty and students on the one hand and the industrial research laboratory on the other. Periodic inspection trips to the industrial research department may be arranged for groups from among the faculty and students. The services of the industrial research staff may be offered to the institution as lecturers and consultants. This subject is discussed more adequately in Chapter 26.

Relations with Local Schools

Similarly, many opportunities are available for friendly and cooperative relations with the local high schools and trade schools. Offering employment to qualified high-school students to do routine work in laboratories is becoming a more prevalent custom. Just as with the institutions of higher learning, industry can contribute to the guidance of school programs, particularly in vocational fields, by letting the school authorities know what it considers to be good training for industry's jobs.

Demonstrations, lectures, and motion pictures which are descriptive of the work, or discoveries of industrial research laboratories will be welcomed by schools; such educational programs are helpful in developing friendly relations with the community.

The opportunities for improving the public relations of industrial research organizations through schools is discussed in a separate chapter. Here they are considered only as one important part of the community.

Any program of assistance offered to the local schools may include similar or related services for the local libraries. These services may take the form of exhibits to be placed in the libraries, or lectures presented to the public under the joint auspices of the library and the research department.

Relations with Union Leaders

The influence of local labor union leaders in a community should be considered in any program designed to create and maintain good public relations. An appreciation by them of the role of industrial research as a potential force to create more jobs is important.

As part of the general public relations program, publicity in the community should show the increased earning power and job security that have come to employees through industrial research.

Relations with Stockholders

Given accurate information and an explanation of motives and problems, a stockholder is likely to be a strong, loyal, intelligent supporter and defender of the business. Where stockholders are a part of the community, sound stockholder relations and sound community relations are supplementary. If there are any stockholders in the community, their aid should be enlisted in the program of community relations. The proper channels for reaching them with the desired information and explanation of motives are determined by the number of stockholders in the community. Where there are a large number resident locally, community relations programs and stockholder relations programs can almost be merged.

Evidence of the growing interest shown by stockholders in research is cited by Maurice Holland: "A recent study indicates that the average stockholder places research fourth in a list of fifteen subjects covering corporation activities which they prefer to see reported." [3]

Civic Clubs

"Service clubs," charity organizations, and other community groups are composed of "substantial people, affluent and good mixers. They want to see their city prosper. They may be on a series of overlapping committees and boards of directors, knitting into one big pattern the controls of much of the community's social, charitable, financial, commercial, and industrial life." A qualified representative of an industrial research organization is usually welcomed into membership in such a group. Participation in the activities of the group is certain to aid knowledge of the community and to provide opportunities for improving community relations.

Contributions

It goes without saying that good community relations require a co-operative attitude toward community activities and a reasonable participation in contributions to worthy causes.

Relations with Local Newspapers

Newspapers—both daily and weekly—are immediately available friends for local industrial organizations, if their friendship is earned. Their circulation reaches a selected public which is receptive to any news that affects, or occurs in, that community.

Representatives of news outlets are constantly searching for local news. The company representative who builds up, in the minds of local news gatherers, a confidence in his sincerity, accuracy, and willingness to help, can do much to further the public relations as well as community relations of his company or his department.

There are about five times as many weekly papers as there are dailies. They are essentially local in their editing, and concentrate on news of direct importance to their community. Stories for these newspapers are best prepared locally for local consumption. Usually they have a greater reader loyalty than the large dailies.

Radio Stations

Radio stations usually have regularly scheduled periods for broadcasting of news, some of which may be sponsored by a commercial organization, and some offered as a public service by the station. The news periods are limited in time; consequently, the news included is highly selective; only news of the most important events can be included. But, like newspapers, radio stations seek news of interest to their listeners, and radio news editors welcome assistance in finding and reporting news of definite interest, local or otherwise.

Relations with Government Agencies

Both industrial research and government are, in the aggregate, so complex that the individual is likely to be awed in his contemplation of relationships between the two. It is not difficult, however, to maintain an accurate perspective if these relationships are viewed in the light of the village druggist and his home-town council. Just as international finance is essentially the family budgeting multiplied to the *n*th power, so are industry-government relations the *n*th power of simple, home-town affairs.

Industrial research, individually and collectively, is expected to be a good citizen in the body politic, just as is the local druggist. His citizenship obligations include participation by voice and vote in choosing his community administration and framing its ordinances, readiness in contributing his specialized knowledge and experience for the benefit of his community, scrupulous observance of the local statutes (whether he voted for them or not), friendly assistance to the village constable, and unremitting vigilance in combating abuse, graft, and incompetence on the part of local officials.

Industrial research leaders personally and through their associations ought to consider it their duty to voice their appraisal of what in their opinion is to the public interest in matters of government action or proposal, particularly in matters in which their specialized knowledge, experience, and judgment can make a special contribution.

Industrial research experience and judgment rank high in many matters deemed advisable for governmental regulation, such as:

Monopoly Practices, Cartels, and Antitrust Legislation

At what point does industrial co-operation to improve service and quality, raise wages, increase safety, and lower prices—all beneficial to society—become collusion inimical to the public interest? Legislation is continually subject to amendment in efforts to hit upon that elusive optimum point. The voice of industrial research honestly sounded can do much to guide legislation closer toward this ideal.

Industrial research consists largely of accumulating and interpreting data to prove or disprove various technical hypotheses. Its group associations are in excellent tactical position to gather and interpret facts and statistics which might direct legislative action more intelligently and help to avoid some of the unexpected and undesirable results of such legislation.

Patents

No other group in society has so great a stake in patent matters as research, and no group aside from patent attorneys approaches its day-to-day experience with patent questions. Industrial research, therefore, knowing so thoroughly the value of the patent system to our way of life and its shortcomings and abuses as well, carries a tremendous obligation of patent leadership, which it cannot lay aside.

It is not the purpose in this chapter to assay patent policies. Public relations policies and practices, however, in so far as industrial research leadership is concerned, require certain fundamental understandings of American law and practices.

First, an invention is a legal property, the product of an individual's effort, which he is constitutionally free to use, store, give away, or sell, just as he is free to sleep under a wool blanket or any other kind he chooses. To be sure, he has no right to fleece his neighbor's sheep to get the wool to make it, or to use the blanket to smother his mother-in-law, any more than he has the right to steal the material of invention or to use it contrary to defined law.

Second, a patent is a contract between society and an inventor—a contract which gives each certain advantages and which imposes on each certain obligations.

In exchange for making known the invention and eventual title to it, society contracts to protect the inventor's property and guarantees for a period of years his exclusive use of it, to employ as freely as any other property he may own. The inventor's obligation is adequate disclosure and relinquishment of title at the end of the period of protection.

A cardinal job of public relations for industrial research people, individually and collectively, is to emphasize these two fundamentals wherever possible throughout society for the purpose of promoting clear thought on the complex, perhaps even muddled, patent debate.

Furthermore, the leaders of industrial research might well advocate, in their own companies and through their associations, self-discipline and co-operative self-regulation of industry toward certain types of "nuisance" patents and the concept of *bona fide* invention.

Industrial research leaders have a definite responsibility to preach the gospel of a sane patent system. It is not necessary to gather the opinions of many men to piece together such a philosophy. It was stated quite adequately by Judge John J. Parker, on the occasion of the fiftieth anniversary of the founding of the Section of Patent, Trade-Mark, and Copyright Law of the American Bar Association.[5] Relations with government agencies concerning patents, that are conducted in accordance with the philosophy expressed by Judge Parker, may be expected to work for the best interests of both industrial research and society at large.

Scientific Agencies of Government

Just as the local druggist (if he is to have good public relations) is expected to contribute his specialized knowledge and experience for the benefit of his community, industrial research is obligated to co-operate with society's governmental scientific agencies. At the same time, the druggist would rightfully object to coaching from the town clerk in compounding prescriptions.

During the past few years the question of the permissible scope of research by government agencies has received considerable attention from leaders in industry, government, and science. Industrial research's honest opinion by right of its knowledge and experience should be accorded much weight in eventual decisions.

Considerable discussion to aid such a decision would be merited in the example of the Bureau of Mines program on liquid fuels from nonpetroleum sources, and its industrial implications. R. E. Wilson[6] presented a comprehensive analysis of the situation, indicating what he considered to be the proper sphere of investigation and research by the government. In general, he recommended that the government agencies obtain the basic background information on oil shale, coal utilization, tar sands, etc., and perform the necessary fundamental research work. Some pilot plant and full-scale tests should then be carried out with industry's co-operation on the most promising methods.

Concerning co-operation of the petroleum industry with the government, Dr. Wilson said:

> If the Bureau of Mines is in general accord with the principles and the program [on liquid fuels from nonpetroleum sources] outlined, the writer is of the opinion that the petroleum industry would be willing, if the government so requested, to set up an advisory committee of technologists, well versed in these fields, to bring together and analyze existing data from various sources. On the basis of this correlation of information, they could advise and co-operate in recommending detailed research programs, designing plants, and keeping the investigations guided along the most useful and practical lines.

Such a concrete proposal could be the basis for co-operation between industry and government in any field of research.

Control of Foods, Drugs, etc.

Government activities in the field of food and drug laws and related control and enforcement are of interest to many industrial research organizations. It is generally conceded that the job being done by the government agencies in this field is of a good caliber, and necessary as a means of protecting not only the public, but also the large majority of ethical producers, from the small group of unscrupulous men. Industry has much in the way of talent and facilities to contribute in co-operation with government agencies in setting up suitable standards and in controlling unethical abuses.

Agencies for the Protection of the Employee

The world-wide trend is toward social security legislation of the familiar wage-hour type. Few people at present take issue with the objectives of such legislation—the objectives of greater economic security and increased economic opportunity for the individual. In a complex world society, however, it is exceedingly difficult to distinguish between those measures which are truly progressive and those attractive but illusory proposals which result in a net loss in the economic status of the average individual. The welfare of employees in technical and research fields is a phase of the larger subject that deserves the attention of research management within its own organizations and the attention of technical societies in industry at large.

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CHAPTER XXVI

Relations with the Educational System

Universities: General

Industrial research depends heavily on the educational system of a country. Industry obtains from the universities the scientifically trained personnel who man its research laboratories; it depends upon the universities largely for the broadening of fundamental knowledge in the sciences, which is the foundation upon which industrial applications are built; it seeks the advice and help of many of the leaders in academic research and perhaps too frequently tempts them away from educational work. Of course education, in return, derives much of its strength from industry and industrial research.

The importance of scientifically trained personnel in the national economy was first impressed forcibly upon American industry during World War I. For many years Germany had been granting hundreds of doctorates in the sciences per year, while organized graduate training in science was in its infancy in this country. To illustrate the value of co-operation between industry and the universities in that country, one need only recall the one instance of Haber's development of a process for synthesizing ammonia, which made Germany independent of the outside world for the production of explosives.

The period immediately following World War I was marked by an unprecedented expansion in the training of scientific personnel in the United States and in the demand for their services in industrial research and development. In the twenty years between 1920 and 1940 the personnel employed in our research laboratories increased from 7,300 to 70,000.[10] During that period the universities and industry were kept equally busy, each with its own phase of the

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This chapter by H. N. Stephens, Director of Research, Minnesota Mining and Manufacturing Co.

common problem of coping with the rapidly expanding body of scientific knowledge. In the process each stimulated the other. Advances in the fundamentals, made largely in university laboratories, have stimulated industry to applications, and advances in applications have posed new fundamental problems to the pure scientist.

The chief organized medium of exchange which brings the universities and industry together is scientific and technological literature, in which the United States became the unquestioned leader during the period between the two World Wars. Two notable trends in that literature have been: the increasing number and the scientific value of contributions from industrial research laboratories, and the increasing number of contributions from university laboratories which have a direct bearing on industrial problems. The convergence of interests of these two groups is an indication of the advance in scientific and technological maturity of the United States as a nation, and sets the stage for more and more fruitful co-operation between the groups in the future.

Other media of exchange between industry and the universities are less formally organized but hardly less important. Leaders in both fields of research maintain a broad personal acquaintanceship and enjoy the common ground for meeting, even those from distant parts of the country, which is provided at meetings of the various scientific and professional societies.

Also, we have the type of contact which is purely on the basis of personal friendship or association. Obviously, the benefits to be derived from this are the same as those which come from contacts made within the framework of an organization.

To sum up, the cross-fertilization of ideas takes place in many strange and unexpected ways. Whether it be through the medium of scientific literature or through personal contacts, the one essential condition is exposure to different points of view. If exposure is guided by intelligence and is frequent enough, the laws of probability require that sooner or later the wind will blow in the right direction.

In many cases, an immediate result of the cross-fertilization of ideas is collaboration between the university and industry on a specific problem of instrument design or experimental technique, which may be freely undertaken (except in the case of instrument manufacturers) without the intrusion of questions of secrecy or patent protection. Other natural results may be the retaining of a faculty member as a specialized consultant or the establishment of university fellowships or sponsored projects.

Specialized Consultants from Universities

The major function of a university and of its faculty is to train students. Therefore, the common practice in industry of retaining university professors as consultants deserves scrutiny from several angles. In the first place, the question is asked whether the professor is betraying the trust placed in him for the training of students by diluting his efforts for the sake of additional income. On the other hand, is industry killing the goose that lays the golden egg by handicapping the training of technical men through distracting the most competent of the educators?

Opinion is not unanimous on these questions but appears to be strongly in the negative in each instance. A representative sample of opinion from deans of colleges of engineering and directors of research also reveals a striking similarity in point of view between the two groups and may be summarized as follows:

The able university professor who devotes part time to consulting work in industry acquires a broadened point of view and dynamic approach to his teaching duties which more than compensate for loss of time from the university, provided, of course, that the consulting work is kept within reasonable limits. In addition, the increment to income aids the university in keeping these able men in academic work which otherwise might compare very unfavorably, financially, with industrial opportunities. Similarly, from the standpoint of industry, the consultant not only contributes valuable specialized advice and help on research problems, but through his contacts with industry makes his educational efforts much more effective and turns out men better adapted to the needs of industrial research.

Industrial research organizations vary widely in the extent to which they make use of consultants from university faculties and in the type of service they expect. Some companies use consultants chiefly on a per job basis, when some specific problem arises. Others retain consultants on a more or less permanent basis, for an annual fee. Some expect contributions only within a narrow field of specialization, while others expect assistance and stimulation of ideas over a much broader range. Some make extensive use of consultants and express great satisfaction with their value, but there are also those who have not been greatly impressed by the few experiments they have tried. There appears to be no correlation between the extent or nature of the use of consultants and the nature or diversity of interests of the industry which engages them. It must be concluded, therefore, that personal preferences, perhaps in some cases tempered by tradition, play an important role in determining the policy of a given company.

In spite of the wide variations in opinion and practice, it would appear that all reasonable parties concerned could agree with the prerequisites for a satisfactory relationship set forth by Dr. W. R. Veazy of the Dow Chemical Company, who writes,

> . . . No arrangement should be tolerated which is merely a method of giving financial aid to a school or faculty member. Such arrangements are never of much benefit to either party. There should be full measure of value both ways. This means that specialized consultants should be employed and should accept employment only where a real need exists.

The practice of using consultants from universities has been steadily increasing and was given added impetus by the war. At least partly because of the severe shortage of technical manpower in industry, the younger men in university faculties have become more and more involved and one unfortunate result may follow. Many of these younger men are being attracted to permanent positions in industry and may leave serious gaps in the universities.

Research Projects in Universities

In recent years there has been a very rapid increase in industrial sponsorship of work in university laboratories. Surveys made by the National Research Council reveal an increase from 95 to 956 in the number of scholarships, fellowships, and grants between 1929 and 1944.[6, 18] Of these, the numbers placed in college and university laboratories were 94 and 807 respectively. Examination of the descriptions of the sponsored work for 1944 further reveals that a large proportion are designated for more or less specific projects.

Keyes [7, 11] has declared, "The primary mistake that has been made in the past has been that the industries have forced upon the university the type of problem which is not fundamental in nature and which may be classified under the head of commercial research."

Coolidge,[3] on the other hand, deplores the "marked tendency for the college to become both application and patent minded, this with the entirely praiseworthy purpose of earning money to finance its research."

Whether industry has forced problems upon the university, or whether the shoe has been on the other foot, is a problem we shall not debate here. The result is the same in either case. It is a fact that there has been a great increase, during recent years, in the amount of work being done in the universities on industrial problems. Defenders of this trend [1, 5, 8, 13, 14] take the position that it is better for universities to work on research problems whose solution will be of immediate benefit to society than to pick problems with no obvious application just for the sake of being able to certify them "99 44/100 per cent pure" science. In addition, work on a problem sponsored by industry offers the graduate student an opportunity to consult with leaders in industrial research and thereby to broaden his views.

As long as a university professor is acting only as a consultant to industry, without the use of university supplies or facilities, the institution can logically take a detached attitude and balance the benefits against actual loss of time from regular duties. When facilities, particularly of a tax-supported university, are used for the exclusive benefit of one industrial concern, however, a fundamental question of policy is raised. This question becomes a particularly embarrassing one if the work results in, or assists in, obtaining a patent for an individual company. If logic is to prevail, the university must take the position that public facilities cannot be used to create, or assist in creating, a private monopoly.

It follows, therefore, that if patents result from the work, they must not be exclusively held or licensed. On the other hand, it is common experience and common sense that an industrial concern will hesitate to take the financial risk of supporting a new venture unless the prospect of profits outweighs the risk of loss.

The question of patents has probably placed more barriers in the way of co-operative research projects between industry and the universities than any other single issue. Some universities have held to the position that a public institution cannot assist in creating a private monopoly and have discouraged any projects whose sponsors desired patent protection. At the other extreme are institutions which have allowed the sponsor full control of patent rights. Between these two extremes are to be found a number of intermediate positions, which involve either a limitation on the patent monopoly or some sharing of patent rights by the university. In general, the trend during the past few years has been in favor of a realistic attitude toward the problems of the industrial sponsor. More institutions are attempting to find ways to resolve the patent problem to the satisfaction of industry, with due regard for the problems of the educational institution.

Research Institutes and Foundations

It is apparent that an *extensive* program of co-operative research cannot be added to the normal activities of a university without providing for its administration. In some institutions provision is made by simply adding these duties to those of the dean or of the president's office. In other cases, the university has considered industrial co-operation to be of sufficient importance to warrant setting up a separate organization with no other duties. Two general methods have been employed in providing this organization, one involving the creation of a special department within the university, and the other the creation of a research foundation as a separate corporate entity.

The university research foundation is a relatively recent development but has already attracted a great deal of attention. Part of the pattern for these organizations was set by the Research Corporation of New York, which for a number of years has been handling patent matters for some universities. Probably the two most highly developed examples are those serving Purdue University and Ohio State University.[2, 4, 15]

From a purely business standpoint these foundations may be considered as non-profit business agencies, with the purpose of promoting industrial sponsorship of research in universities. They negotiate contracts with industry for work which is to be done in university laboratories; they may own and transfer title to patents and they may accept gifts and bequests. Profits from their operations are used to support research in the respective universities which they serve.

It is characteristic of the governing bodies of university research foundations that they have substantial representation from business.

General policy is to exact from industry a fair, but not burdensome, toll for patent rights and to arrive at a practical policy to determine the extent to which exclusive rights are granted. Details of patent policy are still in a more or less fluid condition and the tendency is to adapt them to each individual case.

In spite of the fact that several research foundations and institutes have rendered valuable services to the institutions they represent and to industry, it may be appropriate to sound a note of warning against the indiscriminate entry of universities and colleges into this field of activity. There appears to be a legitimate place for some such organizations; but on the other hand, there may be a definite limit to the number which can be expected to operate successfully in normal times.

Industrial Sponsorship of Pure Research

There are numerous familiar instances in which industrialists, as individuals, have donated or bequeathed funds to support broad educational objectives, including scholarships and fellowships for outstanding students. Corporations, with their ever-present need for considering the interests and wishes of their stockholders, are less inclined to pure philanthropy than individuals, and the motives which actuate an industrial concern to sponsor pure research are somewhat different from those of an individual. In general, the corporation expects some return from its expenditure.

Industrial sponsorship of pure research, by means of fellowships or scholarships, returns fewer tangible benefits than those from specific, designated projects. But the fact that there has been a steady increase in the number of companies supporting such research raises the question whether the benefits may not be just as real.[6, 18] The duPont fellowships in chemistry, for instance, are now awarded in twenty-one universities. They were started in 1918, during a severe shortage of chemists, presumably in the hope that any stimulation of interest in graduate work in that field would tend to increase the supply of well-trained chemists and indirectly benefit the sponsor. In addition, it might reasonably be hoped that favorable publicity surrounding fellowships with no strings attached would attract a larger number of prospective technical employees. Finally, there is the less tangible benefit, from the point of view of an individual company, derived from a general advance of knowledge in the field of activity of the sponsor.

Fellowships in pure science, therefore, are not to be regarded as only philanthropy even when the company makes no stipulation regarding subject matter of the research. It is interesting to note, in passing, the recent announcement by Imperial Chemical Industries [17] of the establishment of fellowships at nine British universities, each carrying an annual stipend of six hundred pounds. The announced purpose of these fellowships is to ". . . strengthen a school of an essential subject which is temporarily weak, adequately assist one already strong, and not attempt to do something which is manifestly much better done elsewhere." Administration is left completely to the universities designated.

In addition to fellowships which are free from restrictions as to subject matter, a considerable amount of fundamental research is being sponsored by various industrial firms in designated fields. The designation in some cases is precise, but in others a great deal of freedom is permitted in the choice of specific problems. Arrangements in many cases are influenced greatly by the personal relationships between the director of research and the professor under whom the work is to be done, and hence practices vary widely.

The Co-operative Plan

In the fall of 1906 an experiment was started in engineering education at the University of Cincinnati, which was the result of the devotion of one man to an idea.[12] The idea was that the training of an engineer, to be most effective, ought to include practical experience, integrated with formal instruction. The specific plan which was put into effect at Cincinnati was to pair off students in alternate weeks of instruction at the university and employment in industry, each pair of students holding a continuous job. Local industry gave support to the plan, not only by assisting in obtaining acceptance of the plan by the university, but by contracting to provide jobs for the half-time students.

Since the inception of the co-operative plan at Cincinnati, it has spread to universities and colleges scattered over the whole country. In principle, the various plans are almost identical, but the length of the alternating periods of work and study vary widely, from one week in the case of the University of Cincinnati to sixteen weeks in the case of Wayne University. It appears that the widest acceptance and support of the plan has come from the mechanical and electrical industries.

Selection and Placement of Personnel

In recent years, competition for the service of the most promising technical graduates has become so keen that industrial firms have become more and more active in scouting the universities for prospective employees. In the more leisurely 1930's it was common practice for company representatives to visit the universities in March or April and interview members of the graduating classes. As competition increased, however, the representatives planned their visits farther and farther ahead of graduation, until it became accepted practice to scout in the late fall. This trend has been paralleled by an increase in the number of companies visiting the universities. The latter, therefore, have been faced with the problem of arranging interviews between members of constantly growing senior classes and a continuously increasing number of interviewers. The result has been that most technical schools have delegated to one man from each department, or unit, responsibility for these personnel relationships.

The Personal Factor in Public Relations

In fostering public relations, if an industry, or more specifically an industrial research organization, presents a highly organized and artificial "front" to the universities, without the benefit of personal relationships to back it up, the result will be far from that desired.

The best public relations are the summation of good personal relations. The reputation of a company in university circles is largely determined by the reputation of its men, by reports received by professors from former students and by other factors which ultimately rest on personal relations. No amount of organization in public relations will modify significantly the esteem in which a company is held as a result of the aggregate personal relationships. Therefore, if any formal organization is justified along the lines of public relations, it might well be directed toward promoting selected personal contacts.

The Secondary School System: General

The broadest contacts between industry and the educational system, considering the proportion of the population involved, are at the secondary-school level. Only a minor proportion of the total of industrial employees are college graduates. In research laboratories, however, the ratio is usually about one to one, and responsibility for performing the functions of research rests almost entirely upon those with professional scientific training. It is not surprising, therefore, that industrial research has concerned itself primarily with relationships at the level of higher education. At present, little organized effort is directed by research groups toward relationships with the secondary-school system, either on a community or on a broader basis.

There are, however, two reasons for research organizations to be interested in the secondary-school system. First, it is the source of raw material out of which technical graduates are made, and second, it provides directly a considerable proportion of research assistants and technicians who are employed in industrial laboratories.

The research assistant admittedly occupies a subordinate position in the laboratory, but his importance is sometimes underrated by professionally trained men. The primary function of the assistant, of course, is to increase the output from the trained worker he assists. As the precise value of the increase in an individual case depends both on direction and on the qualities of the assistant, the variation in the factor is large. There is also, however, a secondary and sometimes more important function of the assistant, which depends entirely on his innate capacity, ingenuity, or curiosity. Not infrequently the assistant will develop ideas or try experiments which lead to valuable results simply because of his limited knowledge of what cannot be done. Usually assistance is required from trained personnel in order to capitalize on such "bootleg" ideas or experiments, but the chain of events might never have been started by anyone encumbered with the inhibitions imposed by a scientific education.

The training and selection of research assistants is a problem which has floated in the outer fringe of consciousness of organized research but which has yet to be taken seriously enough to promote organized action. It must be admitted that there exists now a very meager basis for opinion as to what the training of a research assistant should be, or whether it could be accomplished more rapidly and more uniformly by organized methods than by personal instruction by supervisors, who vary widely in their ability to teach.

It has been left to the universities and to natural processes of selection, including economic factors, to determine who shall be given professional education. No extensive concern has been shown by industry with respect to the preparation for screening, the screening process itself, or the loss of promising candidates through other selective processes. There has been a considerable amount of vague, negative criticism, a much smaller amount of constructive criticism, and very little action in connection with the whole problem of secondary education as it relates to the creation of a supply of professionally trained scientists. If it is admitted that both the universities and the secondary schools are doing their jobs satisfactorily, industrial research can afford to ignore the question and direct its effort where it is needed; if not, there is a challenge to serious thought and action.

A notable exception to the indifference of industry to the secondary-school problem is represented by the Science Talent Search, sponsored by Westinghouse Electric Corporation.[16] The scholarships awarded under this program will not only stimulate interest and competition in scientific subjects in the high schools but will also bring returns to the sponsor in favorable publicity and good will, the value of which may far exceed the financial outlay.

Another adventure in public relations with the high schools, of quite a different sort, is the one sponsored by Chrysler Corporation during the summer of 1943.[9] Seventy high-school teachers and officials, representing six states, were invited into the company apprentice school for eight weeks of combined work and conferences. Judging from the assembled comments of those who participated, the teachers acquired, during that period, a new appreciation of some of the goals of secondary education, and in addition, had an opportunity to broaden their general outlook by seeing a large corporation from the inside. The reason for mentioning this case is not only that it illustrates an existing relation between research and the secondary schools, but that it may be prophetic of future relations which will involve research. Another pioneering experiment along this line was planned by the General Electric Company for the summer of 1945. The company selected from the schools of New York State forty high-school science teachers to be offered a course of study at the research laboratories on recent scientific and technological advances. The teachers were invited to the course at company expense, and instruction was carried on co-operatively between members of the research organization and of the science staff of Union College.

Local Schools

It is an old maxim that charity begins at home. If it is desirable for organized research to take an active interest in the secondary-school systems, that interest ought to start in the community. The interest now is sporadic and largely personal. The first question that arises is whether or not it is worth while for research organizations to direct any substantial effort toward relationships with an educational level so far below the professional. For example, would effort be well spent in organizing visits and talks by research workers in the high schools of the community? Or should that be left, as it is now, to the initiative of the schools? Would an industry obtain any benefits, commensurate with the required effort, from a program directed toward raising the standards of science teachers in the community? Would a research organization be repaid for loss of time and disruption of activities if interested high-school students were invited to visit its laboratories at regular intervals? These are questions which must be given positive answers before much effort will be diverted from the major job of solving research problems.

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CHAPTER XXVII

Relations with Other Firms and Industry

The difference in the relations between industrial research organizations and other elements of industry and the relations between a druggist and other merchants in his village is merely in degree and location. To further our parallel, it is reasonable to assume that the druggist rotates nights-on-call with his fellow druggists, works closely with the local physicians, enters into a Rotary, Lions, or Kiwanis activity, and joins with his neighboring merchants to promote a county fair to bring trade to town. Also he exchanges credit information with both competitors and noncompetitive merchants. He supports, both financially and informationally, the local Better Business Bureau to safeguard the community business ethics.

The typical industrial research organization has relations with competing organizations, complementing and noncompetitive groups, trade associations and technical societies, and has an opportunity to promote or join co-operative programs in the industry and in the profession of industrial research.

The benefit to the public from the work of associations of industrial groups has been great. Quality, service, and value of industrial products has been improved. The present public recognition of such gains is substantial. The opportunity for further gains and further recognition is significant.

Relations with Competitors

The public relations basis for relations with competitors can be no less than courteous co-operation—within limits compatible with competitive position—with the object of aiding industry as a whole to serve the public economically and effectively. This may consist

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largely of co-operation through trade associations, research institutes, and technical societies, but also includes direct co-operation with competitors.

During wartime, the competitive rivalries between most industrial concerns were shelved. Free interchange of technical data and information became prevalent. Some have considered this practice worthy of continuance. Thus, R. J. Dearborn, President of the Texaco Development Company,[1] advocates the exchange of technical data and information as contributing to the advancement of trade and competition. The antitrust laws strictly limit the degree to which this is possible and perhaps these should be clarified to permit greater co-operation. Mr. Dearborn warns against a return to the secret use of unpatented developments, which prevents new developments from reaching current literature. Industrial research leaders should examine all such company policies carefully to avoid those which may be contrary to the public interest.

Co-operative relations with competitors, generally practiced through jointly supported trade association activities, are advantageous not only to the research groups themselves but to the public as a whole. This is particularly true in the fields of standardization, agreements on criteria, specifications, and the promotion of shipping and labeling regulations adequate for proper protection of the public. The basic data for all these is a product of industrial research effort and no other group has a better understanding of such data.

Relations between Noncompetitive Groups

Co-operation among noncompetitive groups—such as the National Association of Manufacturers, the U. S. Chamber of Commerce, the Industrial Research Institute, etc.—is beneficial to industry in general. Groups of this size and scope are suitable for carrying public relations programs to the general public to prove the benefits of research in the private enterprise system, and fostering improved relations between government, business, agriculture, and labor. These groups also can voice informed and carefully considered opinion as to the probable effect of specific legislative programs on the interests of industry and the public. Industrial research representatives have a challenging opportunity for formulating the statements of these associations.

Individual consultation and intercourse between noncompetitive firms are often fruitful in bringing to light areas wherein one complements the other to mutual and public advantage. Industrial research representatives occupy an excellent position for the recognition of such opportunities.

Trade Associations and Technical Societies

Trade associations—such as, for example, the American Petroleum Institute, Chlorine Institute, Steel Founders Society of America, and National Association of Insecticide and Disinfectant Manufacturers—represent co-operative efforts among competitive groups. In general their functions are to set up standards for the industry, improve efficiency by disseminating information on the latest developments, assist financially on or actually perform basic research of value to the industry and the general public, and provide a meeting place where men in the industry can discuss immediate and future problems of importance to all the members. An important result is supplying small business with some of the benefits of industrial research which may be financially beyond the reach of small organizations.

As an example of the aims, organization, and program of a successful trade association research institute, we might cite the Institute of Paper Chemistry.[2] The Institute started as a provincial organization, but its support has become nation-wide. Its efforts have been of considerable value to the paper industry. Similar co-operative industry efforts have benefited many other large industries in this country.

Technical societies such as the American Chemical Society, American Institute of Chemical Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, and American Society for Testing Materials, have much to offer to an individual industrial research organization, particularly to its research employees. These societies provide a medium for publicizing the latest developments in fundamental science and applied technology, which are of inestimable benefit to industry as a whole and to every individual research organization. Meetings of these societies provide opportunities for news stories of accomplishment to be presented to people outside the profession. The work of the societies in educating the public on the value of research, redounds to the benefit of the industrial research organizations.

Co-operative Programs to Improve Public Relations

Individual organizations can do a great deal to improve their own relations with their specific publics, but the group—all industrial research organizations taken together—has much to gain from a co-operative program.

One of the ultimate goals of such programs should be to demonstrate to society that industrial research is identified with the public interest, and that industrial research organizations assume desirable civic and social responsibilities. It is not enough for research men to know this; they should strive to help the public know it, and appreciate its meaning and value.

Another and more positive goal should be to convince the public that industrial research represents capital which industry is "plowing back" in the hope of progress. Profits on established business must be adequate to carry on research on new products and support them through the long "shirt-losing" period when they are not in position to pay their own way. Without sufficient margin of profit no industrial concern can venture into the costly programs necessary for large research undertakings.

Another essential is the protection of the patent system. Without it industrial research would have no alternative but to guard its findings jealously. Hence, were secrecy carried to the extreme, laboratories would have to explore over and over the same ground covered by others—a wasteful multiplication of effort for which all society would pay dearly. The shortcomings of the patent system are relatively minor in comparison with the basic soundness of the mechanism itself.

Another essential to much of present-day industrial research is that some businesses be large enough to do the job. The "big-versus-little-business" debate is another matter that neither the public nor industrial research can afford to let get out of proper perspective. Little business can hardly be expected to develop a new Diesel locomotive. More strikingly, a review of the stupendous problems encountered and solved in the development of the tungsten filament in an ordinary ten-cent electric light bulb is evidence that only a large organization could have marshaled the talent and facilities needed in that particular job.

Actual utilization of the products of industrial research has been, and often still is, precluded by the depreciation provisions in the income tax laws.

For example, suppose a certain product can be produced at a 20 per cent saving in raw material consumption by a change in process developed by industrial research. Management, in considering the change, sees on the one hand that the dollars saved would pay for the new facilities in five years except that, on the other hand, taxes on the profits would run the pay-out to perhaps seven or eight years, and the product itself may well be obsolete within ten years. The incentive for risking venture capital on the discovery thus evaporates. Whereas if industry were permitted to recover its original investment by accelerated depreciation before being taxed on the hypothetical profit, more of these profitable developments might materialize—to the benefit of both industry and the public, the public benefiting either by higher taxable profits over the long run or by lower costs of the products thus produced.

Public educational programs along some of these lines might well be sponsored by associations of industrial research organizations working together co-operatively for their common and the public good.

Scientific Publications

An important aspect of support and co-operation in any research activity is the matter of publishing technical results. The Biblical exhortation, "Freely ye receive: freely give" has commercial practicality in this regard. Within technical circles it is a rather common criticism of some segments of industrial research that "they get all they can but contribute little." Confidential restriction cannot be avoided in a competitive society, yet in all probability far more could be published than has been, if instead of the criterion, "Is it barely possible that this piece of information may be of future value if kept secret?" another were adopted, "Would it be likely to hurt us too much to publish this?"

The published results of research aid the general progress of technical knowledge in an industry. They also contribute to the education of those who interpret research to the public. They influence the schools where trainees for that industry may be studying. They also influence the staff of the laboratory from which they emanate. In many ways the scientific journal is to the research organization its

most immediate means of communication with its most importa
publics. Its importance in the field of public relations for indu
trial research can hardly be exaggerated.

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CHAPTER XXVIII

Research in America and Europe

The $2,000,000,000 atomic bomb which brought Japan to her knees and victory to the Allies was a magnificent symphony of science. French, English, German, Austrian, Danish, and Italian scientists played their parts in the funeral dirge of Hiroshima. Exploding atoms raining down on the "Son of Heaven" and his subjects were more terribly tragic than any Wagnerian opera. Science, like music, knows no boundaries; research respects no antiaircraft batteries in war, or tariff walls in peace.

Industry has taken up the postwar task of beating swords into plowshares and the soil of science is again bearing fruits of peace.

America has been thrust into world leadership in science and technology as well as in political and economic fields. The United States is the trustee of the atomic bomb for the world—and the champion of peace amongst democratic nations.

The purpose of this chapter is to compare the national and industrial research organizations in a number of representative countries in Europe with the research organizations in the United States. Great Britain, France, Germany, and Sweden, Italy, and the U. S. S. R. serve as a representative cross-section of research in Europe and in various political and economic frames of reference, both democratic and otherwise. It is our intention to treat the subject in broad perspective in terms of basic philosophy rather than as a detailed catalogue of institutes and laboratories.* The time span

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This chapter by Maurice Holland, Industrial Research Adviser, in collaboration with Dexter North, National Research Council. A major portion of the material presented in this chapter has appeared in Section V, p. 191, of the National Resources Planning Board Report (1940) written by Dexter North. Much of the material in the original section was based on unpublished reports in the files of National Research Council.

* Representative laboratories and research institutes are listed at the end of this chapter.

covered is roughly 1920 to 1939. Where eminent authorities o the subject are presently available they were asked to prepare summary statement. Parts of such statements are quoted direct with such running comments as seem appropriate.

To establish a bench mark for reference and to budget the rea ing time on each subject nation, a brief and high-spot review o significant trends in industrial research in the United States seem to be first in order.

United States

By far the most significant single factor in the twenty years b tween 1920 and 1939 was the phenomenal growth of research i industry. From fewer than 300 laboratories in the early twenti to over 2,300 in 1939; from a few thousand research workers to ov 70,000 and from a national annual expenditure of 100 million do lars to approximately 400 million is the bare statistical record. Bu the mere measure of size and numbers is only one quantitative bas of comparison. The uniform adoption of industrial research b American industry as a whole, regardless of size of company, field o industry, or geographic location was equally impressive.

A large industrial map locating every industrial research la oratory in the United States, with colored pins designating fiel of industry, clearly indicates a migration of research to the Midd West and definite expansion on the Pacific Coast from Seattle t San Diego and throughout the South and Southwest from Florid to Texas. Not even the depression of the 1930's was able to slo up the march of research progress which reached a peak in the la 1920's. Out of 1,600 industrial laboratories, 150 went out of bus ness in the depression years and 100 new ones were established— net change of 50, or about 3 per cent. Research became solid anchored in the bedrock foundations of American industry. I dustrial executives, bankers, and even stockholders of industri corporations took keen interest in the research activities of the companies; they were "sold on research."

Meanwhile a number of universities were establishing industri research foundations under various forms of organization, of whic Wisconsin Alumni Research Foundation was a prototype. Purdu Michigan, Ohio State Research Foundations, to name but a few o the earlier foundations, were followed by others which in the la

1930's represented about a third of the major universities and colleges. Some university foundations served industries in one locality primarily; others served a single field of industry for which they were especially equipped in staff or facilities. In general they carried on basic research for the middle-sized and large companies, rather than the small. This form of research afforded a proper contact for faculty members and research workers with the technical problems of industry and benefited both. To a lesser degree in the late 1930's industry-sponsored research foundations came into being at an increased rate. They followed the Tanners Council at the University of Cincinnati, the Portland Cement Association, and the Corn Industries Research Foundation, as representative prototypes. In the trend established at that time, this type of research organization is increasing rapidly in scope of activities and industries served.

In brief, the 1920's and 1930's might be characterized as the era of "first growth" in the industrial research crop of laboratories. The phenomenal rate of expansion not only stretched the supply of qualified research workers but conclusively answered the question: "Why do research?" The industrial executive, backed by his banker and encouraged by the active interest of his stockholders, answered: "Research is a paying investment—it is the best form of industrial insurance!"

The American Institute of Public Opinion, of Princeton, New Jersey, places research in fourth position amongst fifteen subjects stockholders want to see in their annual reports.

The next significant development in the broad picture was the emergence from the "Why do research?" to "How do research?" Some officials of the National Research Council, particularly in its Division of Engineering and Industrial Research, and others directly interested in science in industry, came to the belief that better organized and more effectively managed research would pay even higher returns on the investment. Two steps were taken to make available to American industry as a whole the successful experience of older laboratories. Their directors and staff freely made available their broad and successful experiences in a volume titled *Profitable Practice in Industrial Research*, sponsored for publication by the Council and authored by a score of our leading research executives.

The Industrial Research Institute was established in 1938 under Council auspices:

1. To promote, through the co-operative efforts of its members, improved more economical, and more effective techniques of organization, administration, and operation of industrial research.
2. To develop and disseminate information as to the organization, administration, and operation of industrial research.
3. To stimulate and develop an understanding of research as a force in the economic, industrial, and social activity of the nation.
4. To promote high standards in the field of industrial research.

Some ninety companies representative of most major fields of industry and geographically representative of the principal industrial areas of the country meet three times a year in two-day sessions to pool their experiences in organization and administration of research and to further development of a science of management of research.

With the appointment of the Science Advisory Board by President Roosevelt in 1933 through the efforts of an eminent group of scientists, largely drawn from the membership of the National Academy of Sciences and the National Research Council, the government took stock of the scientific and technological resources of the nation. The first report[18] covered a survey of Government research departments and laboratories. The second volume, *Industrial Research*, comes closer to present reader interest. In fact, as a summary of this high-spot review of research in the United States for the period covered, this report will adequately fill the gaps. In the author's opinion the National Resources Planning Board report is the most complete history of an era of industrial research and the most dependable evaluation there is in a field where reference literature is scarce.

GREAT BRITAIN *

Great Britain seems the natural and logical starting point for a review of European research, as it offers an advatangeous basis for comparison with science and industrial research at home.

Industrial research in Great Britain may be divided into that done by industry, research associations, the government, and universities. Outstanding is the active government participation in and subsidy of research through the trade association system, its grants for fellowships and prizes in universities, and the government's own research laboratories. The several groups co-operate extensively and overlapping of activities, unavoidable to some extent, has proved of value in some instances.

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* From material recently furnished by Sir A. P. M. Fleming, Director of Research, Metropolitan-Vickers Co. Ltd., Manchester, England.

Research by Industry

The greatest contributions to industrial research are made by the large manufacturing firms. Unfortunately no authoritative list of such laboratories is available. In 1938 Bernal stated that four-fifths of the industrial research not conducted by the government was done by no more than ten large firms. He estimated the number of firms maintaining research laboratories as between 300 and 600, and the total money spent on industrial research as £2,000,000 (exclusive of government expenditures), although routine testing may be included in this figure. According to A. P. M. Fleming of Metropolitan-Vickers Electrical Company, Ltd., some larger companies have an annual research expenditure in the order of £250,000, the budget of the electrical industry alone being estimated to exceed £1,000,000.

In some industries, groups of financially associated firms pool their research activities, a prominent example of which is Imperial Chemical Industries' large central research laboratories for its subsidiaries. The Sheffield Laboratories of the United Steel Companies provide a similar example in the steel industry.

A report of the Department of Scientific and Industrial Research states that after World War I, "It cannot truthfully be said that industry in general in England was research-conscious." In 1937 E. R. Alexander[1] said, "Industry in England is research-minded and apparently feels that the future prosperity of their own companies and the nation depends upon the results of research," and Holland remarked that the keynote then was "speed-up and extension of industrial research in the national program—particularly the scientific refinement of existing processes and technology and the fullest utilization of the natural resources and advantages which it now possesses."

Contrasted with the United States, the British are more conservative in publication of research results, but more liberal than their continental neighbors, excepting Germany. Although English research executives commonly attend technical meetings, their subordinates do not do so nearly as freely as in this country. The practice of purchasing processes and products developed abroad continued to prevail in the period between the two world conflicts and served as a natural outlet for idle capital.

Until some time after World War I academic research was considered more desirable from a social standpoint than industrial research. Consequently industrial laboratories were unable to recruit men of high caliber in graduate work at the universities. This condition improved greatly in ensuing years and research in fundamental fields became less surrounded by secrecy and restraint. Industry placed more emphasis on research and the social stigma attached to its workers had almost disappeared by the beginning of World War II.

The Research Association Plan

The research association plan in Great Britain is unique, but it developed slowly and many industries continue to be without such services. In 1927 there were sixteen grant-aided research associations with a subscription income of £58,000 from the Department of Scientific and Industrial Research. In 1941 the number had increased to twenty-two with subscriptions of £368,000 and grants of £192,000, and in 1945 there were twenty-eight. A list of the associations existing in 1938 will be found at the end of this chapter. A few associations, notably those on tin, shellac, cement, and brewing, conducted research without benefit of government subsidy and made valuable contributions to the advancement of their industries.

Within certain limitations the research association plan presents some features which might be successfully used in the United States, particularly for small industries, aid for which has been so much discussed here. The system provides opportunity for co-operative research supported by member firms in the industry served and by grants from the Department of Scientific and Industrial Research. It permits firms unable to maintain their own research facilities to derive benefits by pooling resources with others. Some of our university research foundations are serving this need for industry-sponsored research.

Certain objections, however, to the research association plan developed. The principal difficulty was equitable distribution of the results. The larger companies equipped with laboratories naturally derived the greatest benefits and it was difficult to devise a plan for the smaller companies to participate in co-operative research for which they paid their proportionate shares. A partial solution was to encourage small firms to use the laboratory as a foremen's training school in new processes.

According to Sir Frank Heath,[11] former Secretary of the Department of Scientific and Industrial Research, firms failed to make use of new discoveries. A discovery made by one research body might be useful to another industry, yet not be employed. Discoveries were neglected either because of lack of know-how for translation to commercial practice or because of lack of funds. There were instances of industries in need of research being unable to raise the £5,000 per year necessary for government support. Consequently some pooling of efforts by related industries occurred. The Chemical Research Laboratory furnished the plastics industry with research service, the hard fiber industry combined its research with that of the linen industry, and the rayon industry transferred its research to the cotton laboratory.

Reports of the Department of Scientific and Industrial Research show that raising funds for trade associations research was difficult both because manufacturers felt that the chief competitive value of research would be lost if carried out co-operatively, and because of failure to appreciate research in any form. English industry consists largely of small establishments which employ from twenty to one hundred men, and most of which, lacking means for research, find difficulty in maintaining useful contacts with national research projects. Finally, the government itself was reluctant to engage in applied research.

The Government in Research

The position of the government in industrial research is enhanced by the prestige of the Royal Society and the numerous advisory boards and commissions drawn from its distinguished membership. In research matters the Department of Scientific and Industrial Research exerts considerable influence in the higher realms of political affairs. It is reported that not even members of the Privy Council question the appropriations requested by the Department for research projects in the public interest, whenever they are backed by committees of the Royal Society.

Government research in science is directed mainly by three bodies responsible to Committees of the Royal Society: the Departmen of Scientific and Industrial Research (1915), the Medical Researc Council (1920), and the Agricultural Research Council (1931). Th Royal Society also assists in making the nation's research resourc available to the government. The University Grants Committe of the Treasury makes large grants to universities, partly for thei research activities.

The Department of Scientific and Industrial Research is the mos important government agency dealing with research. It receive additional support from industry. At the time of its organizatio its Secretary, Sir Frank Heath, stated its objective to be "to establish a permanent organization for the promotion of scientific an industrial research . . . in peace, even more than in war." Before World War II the department maintained eight special researc establishments, about thirty boards or committees, and co-operate with about twenty industrial research associations, the Medical Research Council and the Agricultural Research Council. Abou twenty government agencies had liaison representatives in the department. The various research establishments, boards, and committees are listed at the end of the chapter.

The directing agency of the department is an advisory counci but actual supervision is in the hands of the special boards an committees. The council initiates specific researches in special institutions, studies problems in particular industries, and administe research studentships and fellowships for recruiting scientific an technical personnel. The boards and committees are concerne mainly with directing authorized research.

The Department's expenditures in 1937–38 were £872,127 gross or £637,200 net. The year's receipts amounted to £234,937, o which fees for paid work were £80,486, contributions to co-operative research £17,966, payments by other government department for services rendered £81,923, and the remainder from miscellaneou sources.

The National Physical Laboratory, one of the research establishments of the Department of Scientific and Industrial Research, wa founded about the beginning of the century, and is the most important of the government's research establishments, especially for maintenance of physical standards and testing instruments. It perform both research and development work and co-operates importantl with the department which supports a considerable part of its research activities. Its aerodynamics laboratory, supported principally by the Air Ministry, is the most important center of aviation research in the British Empire. The laboratory's services are also available to industry on a consulting basis.

Other state-supported research activities under several of the ministries, although outside the control of the Department of Scientific and Industrial Research, are nevertheless in close technical contact with it, and much of their research is of an industrial nature.

Research in Universities

The laboratories of the universities and technological colleges have long been noted for their important contributions to fundamental research. Formerly it was considered in bad taste for academic researchers to permit application of their findings to industry, but this attitude changed in the 1920's when professors began to co-operate with industry by serving as consultants and directing its research projects. Imperial Chemical Industries, Ltd., was instrumental in starting this movement. Thus the university scientist came to enjoy more freedom in industrial research, and provided better postgraduate research opportunities for his students, while at the same time he maintained his social standing. Curricula of technical courses were modernized to meet industry's requirements.

Closer co-operation between universities and industry was also fostered through establishment of fellowships and research grants by industries to assist professors in purchasing materials and equipment. With some exceptions university laboratories have operated under the disadvantage of small size, inadequate equipment, and interference of teaching with research, conditions which have been remedied in some cases by government grants for fundamental research. There has been, however, no organized direction of research in British universities, as in the U. S. S. R. and Germany.

GERMANY

Germany's acknowledged leadership in the applications of science to industry up to the time of the Nazi regime may be attributed principally to four major causes—generous government subsidy of scientific research, the large number of research workers in both pure and applied fields, the inherent characteristics of the Germans which render them ideally suited to research, and the high degree of co-operation between government, universities, and industry.

Contrasts in Research

Contrasting industrial research in Germany with that in the United States, the German government, both national and state, contributed more liberally to its support, but consequently had greater control over it. A higher degree of co-ordination also existed between the German government and industry and universities. Trade association research activities, also under control of the government, were relatively less important than in this country.

With the coming to power of the Nazi regime, applied research became more important than fundamental research by reason of the program for self-sufficiency and preparedness, with the inevitable result that use of substitute materials enormously multiplied applied research problems.

The Government in Research

The foundations of science and research in Germany were more firmly rooted in the state than in any other industrial nation except the U. S. S. R. The national and state governments together supervised and controlled scientfic activities in the government, in universities, and to a lesser extent in industry. The most powerful influence on research was exerted by Prussia, both politically and geographically the most important German state, through its Ministry of Science. By means of grants for fellowships, consulting fees, and guarantees for lecturers, it largely controlled the nation's scientific and research personnel.

Prussia's Physikalische Technische Anstalt, equivalent to the U. S. Bureau of Standards, was the foremost government research institution in Germany, although its plant, equipment, and personnel were much smaller. Also of national importance was the Prussian Staatliches Material Prüfungsamt, or testing materials laboratory, which rendered services similar to those of the Bureau of Standards, the American Society for Testing Materials, and the Underwriters Laboratories. The Chemical Technical Institute in Prussia was concerned with research in chemistry, physics, explosives, metallurgy, and materials testing.

The influence of the national government in Germany was reflected in its sponsorship and support of the Kaiser Wilhelm Institut. Its origin sprang from the convincing of Kaiser Wilhelm II, about 1911, that Germany would lose its industrial leadership unless research facilities were made still more generously available. The Institut directed the activities of many research institutes, numbering thirty-seven in 1937, in the major fields of the natural and social sciences, in medicine, history, law, and the humanities. There is no counterpart of this organization in the United States. Good use might be made here of a modified version of this organization tailored to the needs of the U. S. The depression and postwar inflation shifted almost complete support of these institutes to industry, but in the economic crises of the early 1930's the National Socialist Government lent aid to some of them in return for party support, with the result that the Institut became known as "the general staff of German science."

Even before World War I, Germany was the first nation to recognize the importance of research in science applied to industry. After her defeat she turned to research as a means of overcoming her human and material losses, and there followed what has been termed the most brilliant period in her scientific history. Before the depression she led the world in organized scientific research, of which the many Nobel Prize winners and other highest awards to German scientists is convincing evidence.

Changes Brought About by the Nazi Regime

With the ascendancy of the Nazis the government directed research efforts to the interests of the national economy and preparedness at the expense of fundamental research which is the foundation of all industrial research. Although the Nazis recognized the importance of well-organized research, their policies in other directions often obstructed it. Transfer of technical personnel from the laboratories to manufacturing, and race purges, brought about a shortage of research workers. The expulsion and extinction of the brilliant roster of Jewish scientists was not only one of the great war crimes but may have contributed more than is known to losing the war for the Nazi regime.

In changing from an international to an internal economy Germany greatly increased not only her domestic raw material requirements, labor demands, and energy and transport needs, but also her research requirements. Use of substitute materials enormously multiplied applied research tasks. Delays in authorization of new plants, procurement of building materials, equipment, raw materials, and labor, all of which had to be considered in relation to the national interests, added to the difficulties and seriously delayed important research projects.

After World War I some nations formerly providing large markets for German exports developed new industries or imposed high tariffs, quotas, or embargoes on imports to an extent that seriously reduced Germany's exports in some lines, especially chemicals. To obtain foreign exchange Germany exported technology by licensing foreign firms to use new processes and manufacture new products. Likewise, German firms were granted licenses to use processes developed abroad. Prominent instances of such licenses were those for production of synthetic rubber and aviation gasoline in this country and nylon in Germany. These licenses usually provided for exchange of know-how and other technical information and materially aided technological developments in the countries involved.

The number of workers in pure and applied science has been variously estimated from 50,000 to 75,000. The Verein Deutscher Ingenieure, with a membership of over 30,000 in all fields of science, engineering, and technology, was closely identified with the Prussian Ministry for Science and was one of the largest single forces in the development of applied science in German industry. The Deutsche Chemische Gesellschaft, or German Chemical Society, with its large membership, exerted powerful influence in the chemical process industries.

Co-operation between Industry and Universities

The remarkable industrial growth in Germany following World War I was in large measure due to the effectiveness of the university system of research and its co-ordination with industry. The universities were the heart of German fundamental research. Industry-sponsored post-doctorate research assistants to professors, a system not practiced elsewhere, greatly aided the work. After the Nazis came into power and research directed its efforts to projects yielding immediate results, the number of post-doctorate assistants decreased two-thirds by 1939.

Co-ordination of research, particularly in fundamental lines, between industry and universities in the United States might well take a leaf from the pre-Nazi system of Germany, especially in view of the shortage of graduates created here by the demands of the military services, the results of which will be felt for more than a college generation.

The unemployment situation in Germany up to about 1935 so crowded the universities with students that it seemed doubtful whether industry could absorb all the graduates. As the self-sufficiency program developed, however, unemployment decreased. The three-year program of work-military service for young men, race purges, and the increased tempo of industry combined to reduce university enrollments and created a shortage of research workers, especially in fundamental lines. The research strength of universities was also undermined by replacement of their leaders and department heads with party men and by student interest in party activities. Even if Germany had won the war it is probable that a generation would have been required to restore her universities to their former high place in research.

Research in Industry

Research by industry in Germany before 1939 was characterized by the large number of small and medium-sized companies employing up to fifty research workers, the strong and well-integrated research staffs maintained by most of the larger manufacturers, and, toward the end of the period, the marked trend away from the compartmented research so traditional with the larger companies. The nation's research developed at its most rapid rate between the two World Wars, when its framework for industrial research was unexcelled, except by the United States. A publication of the Verein Deutscher Ingenieure lists 840 industrial research laboratories in Germany before 1930, compared with about 1,600 in the United States in 1920. At that time the total research expenditure in Germany is estimated to have been about half that in this country. In 1939 over 2,300 research laboratories were reported in the United States, a gain probably far greater than Germany's.

The research staffs of some large firms, especially in metals and chemicals, were often larger for a given production than those in the United States. In electric communications, biological chemistry, synthetic organic chemicals, and certain alloys, German industrial research excelled the rest of Europe but was behind the United States in most of these fields. More research workers were employed by the electric communications industry in 1937 than in the United States. German engineers were said to have no superiors in translating research results to commercial practice, but mechanization of manufacturing processes was less advanced than in this country. Likewise, in the development of tools of research, in which Germany had so long excelled, work between the wars continued on a high scale in such fields as X-rays, electron diffraction, and optical instruments.

Several of the research organizations in German industry illustrate the highly integrated manner in which these world-renowned firms operated. That of I. G. Farbenindustrie was one of the most highly developed research organizations in the world. A consolidation of well-integrated competing plants, each with elaborate research facilities, it ultimately covered nearly every field of chemistry. Its successes in dyes, nitrogen, plastics, synthetic rubbers, synthetic liquid fuels, synthetic fibers, organic chemicals, medicinals, and light metals have been remarkable. Aided by the cartel system, it virtually controlled world trade in dyes, nitrogen, and certain other products.

The Siemens-Halske and Siemens-Schuchert combine, one of the largest electrical manufacturers in the world and an approximation of the General Electric and Westinghouse companies combined, operated one of the most extensive research organizations in German industry. In 1937 it was reported to have a staff of two thousand scientists.

Other great research organizations were those of the German General Electric Company, working principally in electric power; Telefunken, which was doing 90 per cent of the research in television and had a larger staff than that in any other country; Krupp in the iron and steel industry; and Zeiss-Ikon in photography.

Trade Associations

Many 'trade associations in Germany maintained extensive research laboratories, notably in the coal, potash, cement, textile, porcelain, and paint and varnish industries. In contrast to trade association activities in America, those in Germany were organized by and under the control of the government. Even nominal control of trade-association research activities by the government can scarcely be as useful to members as the untrammeled industrial research of free trade associations.

FRANCE

Characteristics of French Research

Industrial and fundamental research in France made relatively little progress between the two World Wars, compared with that achieved by other industrial nations in Europe. In 1932 Holland said that France's position in industrial research was about like that of the United States in the late 1890's, when independent inventors such as Edison, Westinghouse, Elihu Thomson, and Sperry played such an important role. This condition was caused by a combination of the individualism characteristic of the French people and the narrow outlook and lack of support of the various governments. Progress was due mainly to the self-sacrifice of scientists and their detachment from industrial considerations, as a result of which it was uneven and sporadic. The feeling that organized research destroyed initiative, and the tendency of the French scientist to forget the results of one investigation in his eagerness to begin another contrasted sharply with the teamwork and greater practical-mindedness of researchers in Germany and the United States. Nevertheless the history of French science is studded with the names of brilliant individuals such as Pasteur, Curie, Fabre, and the Duc de Broglie. This attitude on the part of scientists and the French government toward research may indeed have contributed to the defeat of France in 1940.

Generally speaking, however, the French as a people are not development-minded. A common practice of French scientists was to place in depositories private documents describing individual researches or inventions, for future use, especially against patent applications of others. Research problems finished in the laboratory were often considered as commercially complete and the pilot plant stage of development was not commonly practiced. So long as purchasers were satisfied, manufacturers assumed a passive attitude toward improvements, a condition aptly illustrated in the new yearly models of automobiles in which only minor changes were made. Furthermore, the French often preferred to purchase processes perfected abroad.

Research in Industry

Despite these retarding factors, certain segments of French industry made significant progress from 1920 to 1939. French engineers made valuable contributions in distillation equipment. Noteworthy research accomplishments were made in alloys, metallic carbides, rare gases, naval stores, and coal. French designers of packages for perfumes and cosmetics led the world, and consciously or unconsciously exerted a world-wide influence on industrial design in architecture, equipment, furniture, automobiles, railroads, and other lines, as well as in packaging.

The number of industrial research laboratories in France was comparatively small, but several well-known firms maintained extensive research facilities. Two of the most progressive organizations were those of Établissement Kuhlmann in dyes, organic and heavy chemicals, and those of the Thomson-Houston Company in the electrical industry, with its extensive research facilities mainly for physical testing and chemical analysis of materials used in manufacture, although not comparable with the research laboratories of the great electrical companies of the U. S. Other organizations were active but not outstanding in researches on shale oil, electrometallurgy, chemistry, synthetic fibers, and in organic chemicals. It will be remembered that cellophane and, to a considerable extent, viscose rayon were French developments.

Research Activities of the French Government

The French government's activities in science were in process of reorganization when war began in 1939. Two principal sections of government-controlled research had been established—Le Service Central de la Recherche Scientifique and Le Centre National de la Recherche Scientifique Appliqué, dealing respectively with fundamental and applied research.

Le Service Central de la Recherche Scientifique planned, coordinated, financed, and assembled personnel and resources for research projects. Under its auspices seven institutes and laboratories were established.

Le Centre National de la Recherche Scientifique Appliqué (1938 facilitated and co-ordinated research by government, universities and industry for national defense. Its twenty divisions corresponded to the major industries and several miscellaneous classifications. I maintained laboratories equivalent to those of the Bureau of Standards.

The ministries of Public Health, Public Works, Commerce, Merchant Marine, Posts, Colonies, and the three defense ministries maintained research laboratories. The government tobacco, match, and explosive monopolies, with their laboratories, came under the jurisdiction of some of these ministries, as did certain specialized technical schools. The government administered the educational system, including the advanced technical schools and seventeen state universities, but not all of the state-subsidized educational establishments. It also supervised the numerous learned societies, subsidized scientific missions abroad, and otherwise exercised control over research by means of various regulations.

It might be remarked in closing this section on France that in 1936–37 the Popular Front government of France gave cabinet rank to the Under-Secretary for Scientific Research in the person of Jean Perrin, one of the first instances of such recognition among the democratic nations. It goes without saying that this advance in national organization of research in France went by the board in the political upheavals preceding World War II.

Union of Soviet Socialist Republics

Background of Soviet Research

In the last twenty-five years the U. S. S. R. has emerged as a leader among the world's technically and scientifically advanced countries. Science and research were early made an integral part of the Soviet plan to build up the new state, and her scientific organizations or institutes were and are governmental. The early difficulties of creating a Soviet science and technology and simultaneously carrying out urgent reconstruction work were solved by providing ample money, many men, and enlarged educational facilities.

The rapid changes in the structure of Soviet science have made it difficult to describe its methods of functioning. Suffice it to say that the government's authority over research is all-embracing. This was accomplished through the powers of the Supreme Council and its subsidiary commissions, commissars' and state councils, and the Academy of Science. By means of the framework provided for rationalizing scientific research, the government had definite contr over the direction of all research, both fundamental and applie In this respect the Soviet Union exercised more authority than th Nazi government of Germany.

The research budget increased from an estimated one and a ha million rubles in 1917 to over one billion rubles ($200,000,000) i 1938. The research budget in 1934, according to Bernal, repr sented a far greater proportion of the national wealth than that o any other country devoted to science. As the research workers wer for the most part very poorly trained, employment of many foreig technicians and consultants to assist in starting new industries wa necessary. The large number of mediocre research workers resulte in inefficiency and superficiality, but the mass effort yielded man useful results, some of which were excellent. Considerable improve ment in this situation may be inferred from many recent brillian research accomplishments.

The number of colleges and universities in Russia has increase from 91 to 716 in the last quarter-century and their present enroll ment is about 600,000 students. In early 1941 the number o college-trained chemists was estimated to be 50,000, which was stil insufficient for the growing needs of the Soviet chemical industry

The very nature of the Soviet state necessarily called for empha sis on applied research in relation to the national economy, but th importance of fundamental research was not neglected; some ob servers are of the opinion that excellent results have been achieved more particularly in butadiene (foundation of the synthetic rubbe industry), acetylene, cosmic rays, petroleum, and cold- and drought resistant crops. The fundamental research programs initiated be fore 1939 are reported to have been carried on as originally planned notwithstanding the immense load of applied research brought or by the war and the removal of many research facilities to remot parts of the country.

Soviet Research Institutes

Most fundamental research is conducted in the many researc institutes which work on the fundamentals of physical sciences a they relate to industrial technology. In 1938 the number of suc institutes was reported as 902, with staffs of over 80,000. Many o the commissariats of industry have their own research institutes, a in the coal, oil, nitrogen, shipbuilding, iron and steel, nonferrous metals, chemicals, food, textile, and leather industries. Other important research institutes are concerned with the more fundamental fields of optics, physics, and physical chemistry.

The commissariats of industry also exercise control over research through their authority over technical colleges, the factories, and their laboratories. Several of them were reported to have in their own factories research or experimental stations, including facilities for new processes.

The enormous magnitude of Soviet research is its most outstanding feature. Illustrating the detailed and mass manner of carrying out a project was the coal sampling and testing operation of the Coal Research Institute at Kharkov. From thousands of coal samples, millions of tests were made at a cost of millions of rubles. The variety of projects undertaken by these institutes tended to make more difficult the discovery of new fields of physical knowledge than if concentration had been on fewer subjects.

The Russian Academy of Science, which was founded by Peter the Great about 1724–25, underwent no great organizational changes until about ten years after the Revolution. With the inauguration of the first Five Year Plan, however, it was reorganized for the purpose of advising on the many scientific problems arising from the great social change. Its principal function then was to co-ordinate the scientific activities of all the commissariats in their relation to the planned economy of the state. The Academy also operated numerous laboratories engaged principally in long-term research.

Contrasts in Research

The greatest difference between research in Russia and in Western Europe and the United States is the Soviet's primary objective of the welfare of the workers, rather than the increase of profits from production. Researchers are not expected to show immediate results. The system is highly integrated with the social life of the workers who are encouraged to participate actively in applications of science to industry. Researchers who demonstrate outstanding talent and ability are frequently provided with well-equipped and well-staffed laboratories.

A striking contrast between research in Russia and the United States is the high degree of integration and forward planning of

Soviet Science. The entire research of the country was integrated into the several Five Year Plans so that each project received appropriate consideration on all aspects relating to national welfare. Relations of laboratories and institutes to universities and industry were carefully planned. The industrial and agricultural needs of the country were determined for the next forty years, and research institutes and equipment provided to carry out the program. In this respect the Russians have demonstrated the wisdom of long-range research planning to an extent not hitherto shown in democratic countries.

The large number of research institutes in Russia dwarfs in comparison the United States government's facilities, but the effectiveness of these state-controlled facilities as compared to results obtained under the free enterprise system is open to question. The several Five Year Plans have aided in making the country more self-sufficient, raising the standard of living of the people, and in better preparedness for war.

ITALY

Like other totalitarian states, Italy directed its research activities toward self-sufficiency and preparedness, but less successfully because of her lack of raw materials and of her predominantly agricultural population. As in Germany, emphasis was placed on applied rather than fundamental research.

The National Research Council

In order to control research and relate it to the national economy, the government established the National Research Council in 1921 on lines similar to that in the United States. Its scientific and technical divisions corresponded closely. It was supported by the government, industry, and royalties from patents. Because of lack of results it was reorganized about 1928 and became a permanent consulting agency of the government on all problems of scientific development and progress at home and abroad. It passed upon government loans for plant expansions for which it also gave technical advice, financed government and university research, and controlled Italian representation at international scientific and technical meetings. It endeavored to reduce industrial competition through research, reviewed all research programs of industry, universities, and government, compiled and disseminated technical and scientific bibliographies, and studied foreign developments for possible application to Italian industries.

Research in Industry

In industry the emphasis on self-sufficiency required concentration of resources and research personnel on development of techniques developed abroad, with the result that economically unsound processes were often employed and work in really new fields was neglected. Progress was made, however, in the development of chemical and related products such as pulp and paper, artificial fibers, motor fuel from agricultural materials, low-temperature distillation of lignite, and light metals.

It was estimated that in 1934 there were about 60 industrial research laboratories in the northern Italian industrial area and 200 in the entire country. Probably the biggest and most advanced of these was that of the Montecatini Company, largest Italian chemical company. Just before World War II it authorized 20,000,000 lire for expansion of research facilities, to be known as the Institute Scientifico per Richerche e Sperimentazioni Chemiche, which was to be Italy's finest and most comprehensive research laboratory.

In development of rayon and new textile fibers, Chatillon S. A. Cisa and Snia Viscosa were active, the latter also being active in casein fiber. In boron and iodine compounds and utilization of steam from volcanic fumaroles, Societa Boracifera di Larderello did good work. The Casale Company, Film-Fabriche Riunite Prodotti, and Pirelli Rubber were engaged respectively in nitrogen fixation, photographic film, and synthetic rubber. The Institute of Ceramics investigated domestic clays as replacements for imports, and the Scientific Industrial Research Institute, at Milan, conducted research in various fields.

University Research

Italian universities formerly directed their research mainly along fundamental lines, and as a result turned out comparatively few men qualified for industrial research. Some time after Mussolini came into power, principal emphasis changed to applied research and technical schools concentrated their efforts on training men to meet industry's growing demands. Research on projects of direct value to industry was materially aided by grants in 1938 to five universities.

Scandinavian Countries

The limited natural resources of the Scandinavian countries quit naturally turned their research efforts to development of these mate rials rather than to self-sufficiency, although some work was done to ward remedying deficiencies. The people of these countries posses natural aptitudes for precision work under individual responsibility a bent for scientific thinking, and, in general, a good background o fundamentals. In the period between the two wars their researc workers were noted for engineering skill and accomplishments in basic research. These countries produced such internationally known scientists as the Swedish Nobel, inventor of dynamite, de Laval, inventor of the centrifuge, the Norwegian Birkeland and Eyde, co-developers of the arc process of nitrogen fixation, and the Danish Bohr, famous for his work on atomic structure and biophysics.

Sweden, Norway and Finland have abundant timber resources and have been competing with each other on improvements in processes for recovering cellulose. Norway's important fishery industry, and to a lesser extent Sweden's, were active in research. Norway led in developing hydro-electric power, but Sweden was also active. Research in Denmark was much less important by reason of its small size and predominantly agricultural character, but has been of high order in nuclear physics, biophysics, zymology, hydraulic engineering, and in the dairy and fertilizer industries. Government support of industrial research in these countries was comparatively unimportant in the 1920's, but increased toward the end of the next decade.

Sweden

A large share of Swedish research, both fundamental and applied, has been on cellulose and iron and steel products. She gained a strong position in world trade through development of excellent grades of pulp and paper, including pulp for rayon and smokeless powder, and in later years, paper products and rayon. Extensive research was done on lignin and on tall oil from sulfate pulp, alcohol from sulfite liquor, and protein food material from alcohol yeasts.

Swedish iron ores and steels are world famous. In the absence of coal resources, charcoal was used to produce pig iron, which accounts partly for the purity and high quality of the steels. Much research was done in the fields of ferrous alloys, special high quality finished products, and in the late 1930's, on sponge iron from lower grade ores.

Boliden Mines did important work on by-products from pyrites and other deposits. As the large quantities of arsenic so obtained exerted a depressing influence on world markets, research was undertaken to develop new outlets, among them preservation of wooden poles and piles.

Before the last war the Bofors Company engaged in notable research in tool steel, ordnance, and ballistics. (Who has not heard of the Bofors anti-aircraft gun used by most of the warring nations?) The Asea Company carried on research in power machine construction, the Ericsson Company in electric communications, the Aga Company in household and industrial equipment, and numerous others in different fields. Two associations of manufacturers, one in cement and the other in iron, were active in research on their products and processes. The Consumers' Co-operative Union conducted applied research on products it manufactured.

The Royal Academy of Science (Stockholm) and the Royal Institute for Scientific Engineering (Academy of Engineering Science) conducted important research under strong state subsidy but were not state administered. The Royal Academy engaged in fundamental research in the natural sciences. Affiliated with it are the Nobel Institution and the Institute for Experimental Physics. At the Institute, Professor Manne Siegbahn, equipped with a cyclotron, electron microscope, and diffraction grading equipment, conducted research of a high order on X-rays and nuclear physics in the inter-war period.

The Royal Academy of Engineering Sciences (IVA), a learned society founded shortly after the first World War, was a clearing house for engineering research. It conducted its own research, principally in fuel and heat economy, and to a limited extent co-ordinated research in Sweden. It was supported by industry, the state, and a society for promoting engineering research. Nothing quite like this organization exists in the United States. Here again the United States might learn something of national research organization and co-ordination.

Fundamental research was done mainly at the universities. At the University of Upsala during this period The Svedberg did the most outstanding work in the world on the ultra-centrifuge and it applications to biology and chemistry. The Royal Institute of Technology (Stockholm) was noted for its work on wood and cellulose Industry and government laboratories also engaged in fundamenta research.

Just before the last war centralization and rationalization of scientific and industrial research was proposed to the Swedish Riksdag A central institute supported by government and industry was to have carried out the plan, with committees and research institutes in twenty-two different fields.

The government conducted important research in several institutes, of which three were completed just before the last war: The State Testing Institute or Bureau of Standards, the Aerodynamic Laboratories, and the Hydro-dynamics Laboratory. The Institute of Public Health combined a group of state laboratories working on the borderline between engineering and biology.

The Scandinavian countries are anxious to expand their industrial research programs. Some have sent representatives to this country to study research organizations and to encourage technological co-operation. Numerous industrial developments in these countries should be of interest to American manufacturers.

RESEARCH LABORATORIES AND ORGANIZATIONS IN EUROPE

Great Britain

Department of Scientific and Industrial Research, Special Research establishments (1938):

- National Physical Laboratory, Teddington.
- Geological Survey and Museum, London.
- Fuel Research Station, Greenwich.
- Low Temperature Research Station, Watford.
- Forest Products Research Station, Princes Risborough.
- Chemical Research Laboratory, Teddington.
- Radio Research Station, Slough.

Boards and Committees:

- Building (Materials and Construction) Research Board.
- Committee on Testing Work for the Building Industry.
- Chemistry Research Board.
- Food Investigation Board.
- Committee on Management, Low Temperature Station for Research in Biochemistry and Physics, Cambridge.
- Metallurgy Research Board.
- Road (Materials and Construction) Research Board.
- Water Pollution Research Board.

Atmospheric Pollution Research Board.
Dental Investigation Committee.
Gas Cylinders and Containers Committee.
Illumination Research Committee.
Lubrication Research Committee.
Road Tar Research Committee.
Steel Structure Research Committee.
Committee on the Application of X-ray Methods to Industrial Research.

Trade Associations:

British Cast Iron Research Association.
British Iron and Steel Federation (Iron and Steel Industrial Research Council).
British Refractories Research Association.
British Electrical and Allied Industries Research Association.
British Scientific Instrument Research Association.
British Association of British Paint, Colour, and Varnish Manufacturers.
Institutions of Automobile Engineers Research and Standardization Committee.
British Cotton Industry Research Association.
Linen Industry Research Association.
British Launderers' Research Association.
British Leather Manufacturers' Research Association.
British Boot, Shoe, and Allied Trades' Research Association.
Research Association of British Rubber Manufacturers.
British Association of British Flour Millers.
British Association of Research for the Cocoa, Chocolate, Sugar, Confectionery, and Jam Trades.
British Food Manufacturers' Research Association.
Printing and Allied Trades Research Association.
British Colliery Owners' Research Association.
British Non-Ferrous Metals Research Association.
British Coal Utilization Research Association.
British Pottery Research Association.
International Tin Research and Development Council.
Gas Research Board (sponsored by the Institution of Gas Engineers and the British Gas Federation).
Shellac Research Bureau.
Associated Portland Cement Manufacturers, Ltd.
Institute of Brewing.

GERMANY

German State Council for Research; Departments (1937):

Physics—including mathematics, astronomy, and meteorology.
Chemistry and physical chemistry.
Power materials.
Organic industrial materials, artificial products, rubber, textiles, etc.
Non-ferrous metals.
Geology, including mineralogy and geophysics.
Agriculture and general biology, including zoology and botany.
Forestry and timber research.

Military science and technics.
Electrotechnics.
Mining and smelting.
Iron and steel.
Medicine, including race research and race biology.
Military medicine.

FRANCE

Le Service Central de la Recherche Scientifique: Laboratories and Institutes:

Astro-Physics Service.
Large-Scale Chemistry Laboratory.
Atomic Synthesis Laboratory.
Institute for Textual History.
Magnetic Laboratory.
Physical Institute.

Le Centre National de la Recherche Scientifique Appliqué, divisions:

Water power.
Mines.
Agriculture and fisheries.
Metallurgy.
Chemical industry.
Utilization of fuel (boilers, steam engines, motors, etc.).
Machinery.
Textiles, wood, and leather.
Building construction.
Lighting and heating.
Physical education and sport.
Civil engineering.
Transport.
Communications.
National defense.
Printing, cinemas, etc.
Light industry, furniture, and domestic engineering.
Hygiene.
Nutrition.
Working conditions.

UNION OF SOCIALIST SOVIET REPUBLICS (partial list of Research Institutes)

Academy of Sciences:

Institute of Chemical Physics.
Electro-Physical Institute.
Ural Physico-Technical Institute.
Kharkov Physico-Technical Institute.
Institute of Physical Problems, Moscow (1932).
Institute of Theoretical Geophysics, Moscow (1937).
Colloid-Electrochemical Institute, Moscow (1934).
Physico-Technical Roentgen Institute.
Radium Institute, Leningrad (1922).
Krzhizhanovskii Institute of Energetics, Moscow (1930).
P. N. Lebeder Physical Institute, Moscow (1934).

V. A. Steklov Mathematical Institute.
Physico-Technical Institute, Leningrad (1921).
Roentgenological Institute (1918).
Institute of Chemical Physics, Leningrad (also Moscow).
Physico-Technical Institute, Leningrad.
Biological Institute.
Institute of Human Biology and Medicine.
Geology Institute.
Physico-Technical Institute, Kharkov.
Physico-Technical Institute, Dniepropetrovsk.
Physical Institute.
Plastics Institute, Leningrad.
Biochemical Institute.
Institute of Organic Chemistry.
Institute of Mineral Fuels.
Institute of Chemical Technology, Kharkov.
Leningrad Mining Institute.
Karpov Institute of Physical Chemistry.
Optical Institute, Leningrad.
Institute of Fertilizers and Insectofungicides.
Colloid-Electrochemical Institute.
Institute of General and Inorganic Chemistry.
Magnitogorsk Metallurgical Combine.
Ural Metallurgical Industry.
Balkhash Copper Combine.
Ural Aluminum Industry.
Ural Industrial Institute.
Mendeleev Institute of Chemical Technology.
Institute of the Cotton Industry.
Chemico-Pharmaceutical Institute.
Radium Institute.
Coal Research Institute, Kharkov.

Commissariats of Industry—Research institutes in many industries, including:

Coal
Oil
Nitrogen
Shipbuilding
Ferrous metals
Non-ferrous metals
Chemicals
Foods
Textiles
Leather

SWEDEN

Committees of central research institute proposed to Riksdag (1939):

Committee for the Study of Couplings in High-Voltage Electric Wire and Cables.
Association for Rational Textile Washing.
Forest Scientific Committee.
Welding Committee.
Corrosion Board.
Gas Generator Board.
Air-Conditioning Committee.
Coal-Technical Committee.

Aeronautical Committee.
Shale Committee.
Committee for Domestic Motor Fuel.
Fuel-Technical Committee.
Swedish Iron Masters' Association.
Swedish Cement Association.
Steam Heat Institute.
Charcoal Laboratory.
Cement Laboratory.
Technical X-Ray Central.
Laboratory for Boilers.
Electro-heat Institute.
Central Testing Institute.
Royal Building Board.

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CHAPTER XXIX

Goals and Problems for the Future

Our World

In the brief period of half of one human generation the oute surface of that planet which is known as the earth has become s much better known to its inhabitants that a part of the vanguar of pathfinders is vigorously attempting to develop methods of exploring the limitless space of which our own one world is but a atom. Even before we have learned how to get along with ou fellows here on earth we are literally "looking for new worlds t conquer."

Is the lure of fame and material remuneration the attractio which pulls men away from work on vital problems to the exploration of new and unplotted fields? Probably not. It is far mor probably the challenge of what is most unknown, which provides th stimulation to the imagination—the very characteristics which ar the glamour and motif of research. It has always been this way The authors of many of the world's greatest inventions such as th wheel and the earliest methods of recording facts have never bee known to our present civilization. It has required the relativel recent invention of writing and printing to make sure that histor credits the discoverer.

What is the goal of all research? It is certainly the developmen of better ways of living in this universe of which we are a part—no for just a few but for all. Modern industrial research, primarily se up as a tool for competition in business, must continuously be softened and broadened by the realization on the part of its administrators that the ultimate goal for human efforts is to develop bette

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This chapter by Paul D. V. Manning, Vice President in Charge of Research, International Minerals and Chemical Corp.

ways of living for all. Better methods of making better fertilizers—so that more can be sold at higher profits to shareholders, yes, but better and cheaper plant foods so that all men may have more nutritious foods and higher living standards! All aims can be resolved and restated in like terms. Constant emphasis of these broader principles can so thrill the research worker and make these problems so much more attractive that the scientist is happy in such research and sees the glamour that truly resides in their solution. The new worlds of the universe can wait while people concentrate on learning all that can be found out about the one which we know most. Science does have "practical and social consequences." [1] The danger is that of emphasizing the former without realizing that even in the practical applications of research lie great social benefits, if properly recognized, followed up, and used.

PHOTO. 43. Animal experimentation plays an essential role in nutrition research. (*Courtesy of Armour and Company.*)

Holding Our Own

Without having experienced a war, a generation of the human family tends to lose sight of its ruthlessness and its cost in material things and living standards alone. The urge for material gains, increased living standards, and control of others is a powerful thing, for it has induced almost the entire population of the world to go to war. Can wars be prevented through the general acceptance and proper stressing of the broader objectives of science and living? It is thought that ultimately they can, providing there can be a recognition not only of the need, but of the obligation, of working constantly toward the goal of increased happiness for a greater proportion of the human population. There must be a general confirmation in the minds of thinking men that while the profit incentive is needed as an activator, profit in itself is not the end. It is rather a part of the process by which men may move toward the goal of achieving better living for more and more people. This goal is one which always moves ahead. When its initial standard is reached, the goal itself is seen again, still far ahead. If profit or war is made the only incentive for research, this may well breed war and make it impossible to attain the broad objectives. There are six important steps which must be taken in the process of attaining these ends.

1. Improved and nutritionally satisfactory foods are needed at low costs. Research is making great progress, but further improvements are vitally needed to produce a higher proportion of perfection of products and a lowering of man-hours required per unit of product. Without some such regimentation as communism, there must be an increase in the wages paid to labor (reckoned not in money but in what money will buy) throughout the world, if the goal is to be reached. It follows, of course, that this cannot take place unless there is constantly increasing productivity per man-hour.

2. There must be much better progress than has been made up to the present in education and the development of knowledge of the human mind and sociology. It is a poor commentary on human beings to realize that so little has been done to advance knowledge of people and their improvement, in contrast to the efforts which are put forth to make material gains. Through more research on the human mind and body, conditions can be made such that we may

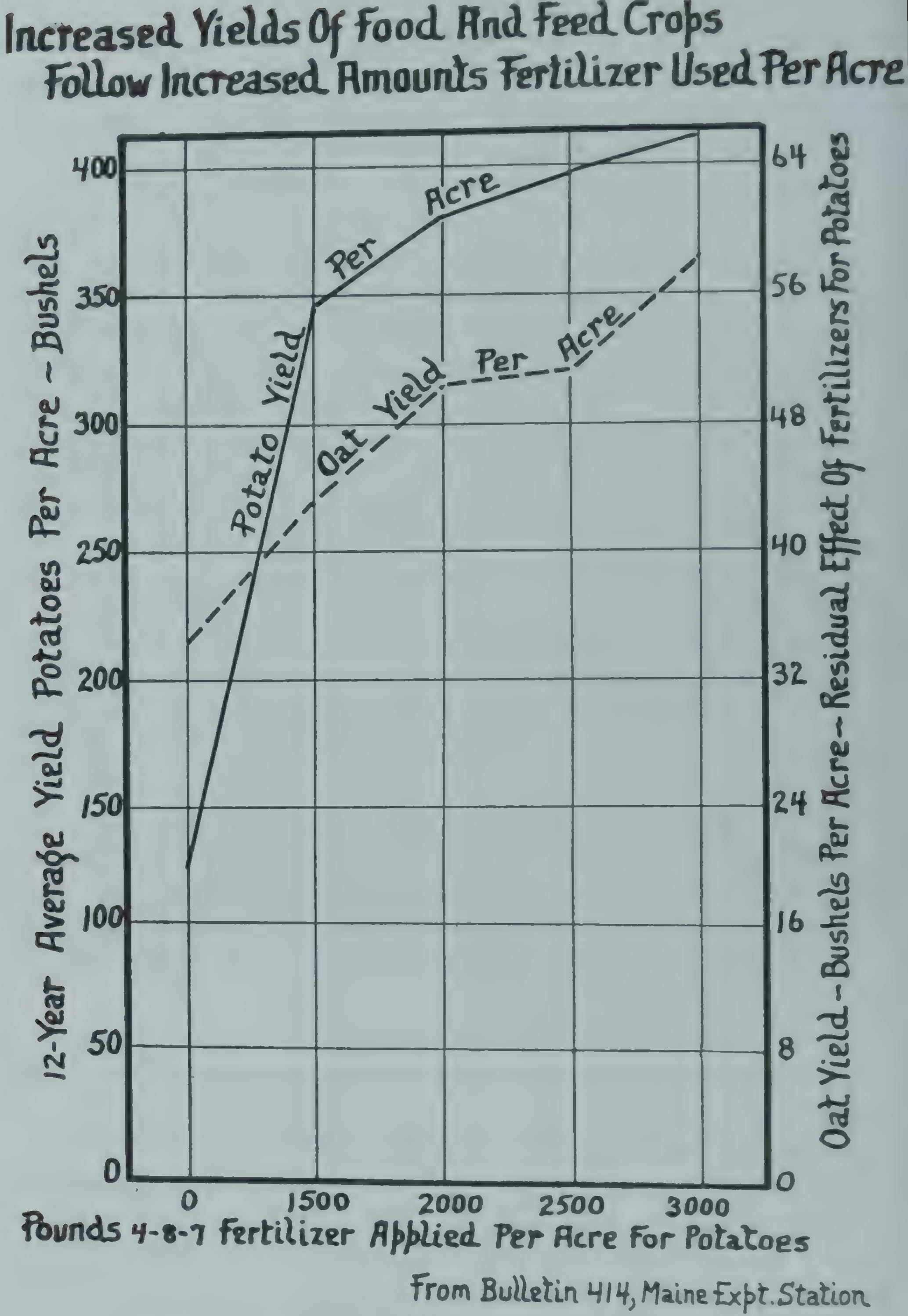
live longer and more useful lives and may use more enjoyably the material things for which we labor so hard.

3. There must be great improvements in the methods of distribution of products from all sources. They must reach a larger proportion of the population of the world more easily and more cheaply. Concentration of products—that is, the removal of unusuable constituents—makes possible their transportation with a correspondingly lowering of unit shipping costs, but even this fails to suffice. Establishment of industries near points where products can be used is one means of aid, which also helps provide the purchasing power among the populations served.

4. There is a constant need for more conveniences and more labor-saving devices in every day life. This includes better-designed and more convenient homes at lower costs. Construction materials must be developed which are proof against fire and the elements. The annual waste and losses caused by fire alone are of tremendous size, besides, of course, the great expenditure made each year for fire protection, insurance, etc. Materials and construction must lend themselves to greater flexibility of arrangement. Improvements are most wanted in filling the needs of the great number of families of low income. Before people can learn to work for those things which make higher living standards, they must know what they are.

5. The production and distribution of low-cost heat and power must be greatly increased. As an example of this need, consider postwar England. Its industries depend to such an extent on obtaining cheap fuel for its manufacturing that at present the entire economic life of its people depends on coal. Atomic power and heat is a great hope and promise.

6. The fullest conservation of natural resources is a vital requirement. Industry seems always to start the exploitation of a natural resource quite wastefully. The most concentrated raw materials are used to produce more pure products which then are deconcentrated through utilization and war. In the production process the recovery is often wasteful. In the end, industry is forced to use the poorer raw materials either at an increased cost or through the development of more efficient processes. More research will produce better processes at the start. It will also prevent the contamination of the air and streams with industrial wastes.



From Bulletin 414, Maine Expt. Station

PHOTO. 44. Typical effect of fertilizer on crop production.

This last war has served to bring home the fact that natural resources are not inexhaustible. Some of them have been drawn upon at such a rate during the war that the end of the best deposits is but a few years ahead and research on the amelioration of the poorer grades is now being rushed. This is true of iron and copper ores. Once the natural resources of any country are stripped, then all that country has are its manpower, its agriculture, and its power from such sources as water. Without such basic resources as fertilizers, even agriculture is lost. This is nearly the situation in England now.

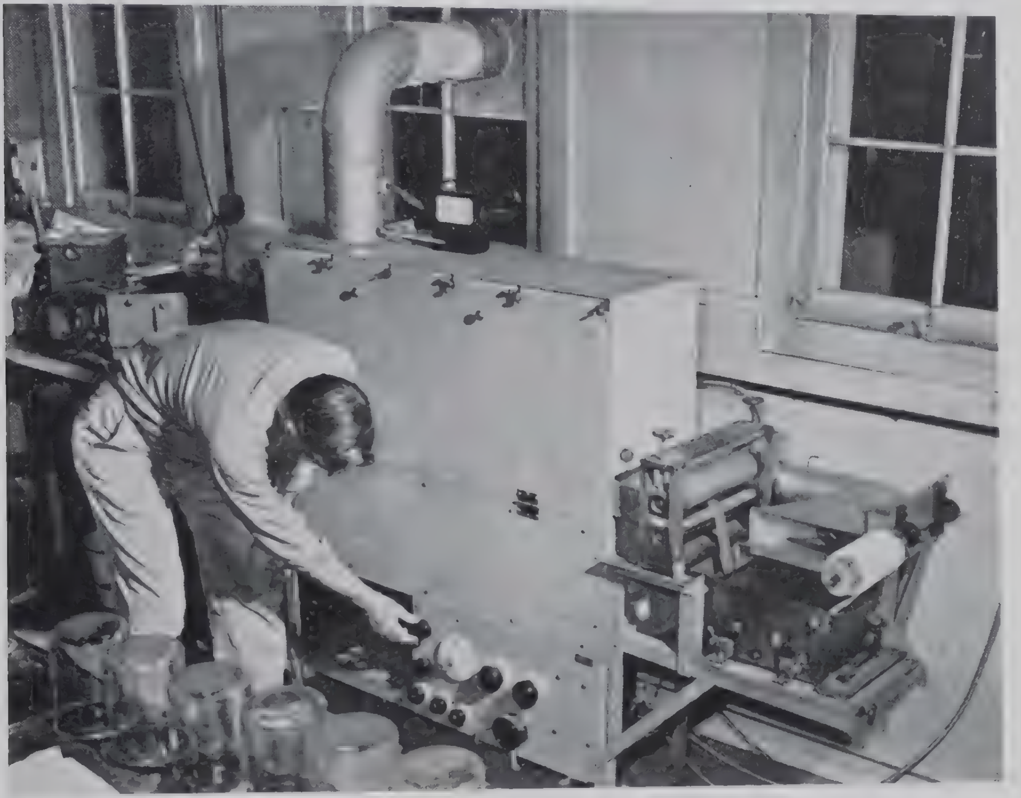


PHOTO. 45. Soil tester. *(Courtesy of the Monsanto Chemical Company.)*

Atomic fission is a process of transforming matter into energy. There must, of course, be a limit on the earth to the amount of matter that can be transformed. Though such a limit will not be reached in many generations, consideration should be given to the future of the world. The need of better and cheaper sources of the relatively scarce fissionable materials presages intensive research on newer methods of prospecting, mining, and ore dressing. Since the

APPROXIMATE COMPOSITION OF THE EARTH'S OUTER CRUST

Element	*Per Cent by Weight*[4]	*Per Cent by Weight*[3]	*Per Cent by Weight*[2]
Oxygen	46.59	46.71	
Silicon	27.72	27.69	
Aluminum	8.13	8.07	
Iron	5.01	5.05	
Calcium	3.63	3.65	
Sodium	2.85	2.75	
Potassium	2.60	2.58	
Magnesium	2.09	2.08	
Titanium	0.63	0.62	
Hydrogen		0.14	
Phosphorus	0.13	0.13	
Carbon	0.09	0.094	
Manganese	0.10	0.090	
Sulfur	0.05	0.052	
Barium		0.050	
Chlorine		0.045	
Chromium		0.035	
Fluorine		0.029	
Zirconium		0.025	
Nickel		0.019	
Strontium		0.018	
Vanadium		0.016	
Cerium, Yttrium		0.014	
Copper		0.010	
Uranium		0.008	
Tungsten		0.005	
Lithium		0.004	
Zinc		0.004	
Columbium, Tantalum		0.003	
Hafnium		0.003	
Thorium		0.002	
Lead		0.002	
Cobalt		0.001	
Boron		0.001	
Beryllium		0.001	
Molybdenum			0.0006
Tin			0.0005
Arsenic			0.00045
Antimony			0.000025
Cadmium			0.000010
Silver			0.000004
Bismuth			0.000003
Mercury			0.0000025
Gold			0.0000001
Platinum			0.000000008
Iridium			0.00000000025
Palladium			0.00000000008
Radium			0.000000000002

(No reliable data are available for estimating the quantities of the other elements.)

oceans and ice cover a large proportion of the surface of the earth, ways of prospecting and mining ores in the earth beneath the sea and under the polar ice caps will be the subject of research.

The raw materials which the inhabitants of the earth have available for life and industry include the atmosphere, water, radiation from the sun and other sources around the earth, and the materials making up what is commonly called the earth's outer crust. Estimates have been made as to the amounts of the different chemical elements in this outer crust. The most authoritative figures are given in the table on page 534.

It is interesting to note that with a few exceptions, those raw materials used to make the most indispensable products are not among the earth's most plentiful substances. For instances, copper, which is twenty-fourth on the list, makes up only one-hundredth of one per cent of the weight of the earth's outer crust. Silver, which could be used in many ways in place of copper, is estimated to make up only four one-millionths of one per cent of the outer crust.

On the other hand, aluminum is the third most plentiful element, totaling 8.13 per cent. Although aluminum is so relatively plentiful, most of the metal made in the United States is produced from bauxite mined in South America. There is much of this ore in this country but the grade is low. Research on ore dressing may obviate the need of transporting the better ore these great distances, or research on the production of aluminum may some day yield a commercial process which can use the poorer ore.

Certainly there is great opportunity in the development of useful materials from the most common elements. Among these are silicon, aluminum, calcium, sodium, potassium, magnesium, etc. Already great progress has been made in production and use of titanium, ninth on the list, in place of lead, for certain purposes, such as paint (lead is thirty-second in the table). Titanium is now being recovered from Florida beach sands in which it exists in low concentrations.

Recent research has resulted in the discovery that silicon can be used in place of carbon in the formation of a whole class of chemical compounds called silicones. This opens up an entirely new field of organic chemistry and, as in the case of the hydrocarbons, the number of possible compounds is great and the characteristics of many of them are such as to make it evident that many of the products will be exceedingly useful. Much of living depends upon carbon and the chemistry of its compounds. It is the twelfth most plentiful element in the earth's crust. When it is realized that the greatest portion of the known facts of chemistry at present relate to organic chemistry and that most of this knowledge is at present the chemistry of carbon, it is not difficult to realize what is ahead in potentialities as to the other elements.

But fundamental research requires time, and lots of it, to build the reservoirs of facts which are drawn upon so heavily for the advances in the applications of science to better living. These applications are needed now and the fundamental research is already late. In this, any time is late. What a difference there would be today in the life of the average Englishman if research carried out years ago had created new reserves of raw material and new sources of power on which the industries of Great Britain could now draw!

China with her millions of people, and many other countries whose inhabitants are only just ahead of starvation even in prosperous times, all point out the need for research to develop industries which can use what their people can produce to make the necessities that will keep them living. Over 50 per cent of the peoples of the world never have enough to eat, while more than half of the remainder frequently face hunger. Even having just enough to eat does not elevate standards of living to what is considered a minimum. Food is only the beginning of needs. Peace certainly cannot be maintained in a world where most of the people are always close to starvation—they have little to lose by war.

Responsibilities come with knowledge, obligations come with having. There have been those in recent years who have stated that too much research has been done—that a moratorium should be declared on it to allow the world to catch up or digest its present technical progress. How could such a process feed the millions who are starving? More research, not less, is needed.

This last war did more in four years to sell research and to bring home its possibilities than any other event could have done, in any other manner. In a way it resulted in overselling; people are now witnessing what amounts almost to the dumping of great sums of money into research by industries, in many cases without any well-defined objectives and certainly without consideration of how the money can be spent most wisely. Thereby research is in danger of becoming an industrial fad and disrepute is almost bound to follow. Many industrialists fail to realize that the great progress made during the war, and credited to research, was in reality the application of the results of fundamental research carried out years before. It is time now to refill these reservoirs and to build new ones.

The matrix of research organizations is now much the same qualitatively as it was before the war, but quantitatively it has greatly changed. Research has now acquired political implications of international proportions. Industrial research is receiving a tremendous "shot in the arm." The university laboratories, already partially depleted as to staff by the war, are being further depleted by the demands of industry. The men remaining now face teaching loads so great, because of this and because of increased enrollment of students, as practically to preclude research. The increased popularity of research has instigated the establishment of a number of new research institutes with the avowed purpose of aiding in regional industrial growth. It does not appear that these will carry out much fundamental research.

In summary of the situation, it now appears that too much emphasis is being placed upon the industrial application of research and too little on fundamental research. At present the government seems to be sponsoring or carrying out most of the basic work. Perhaps this is a good thing. It is probably too early to determine this as yet, but real danger lies ahead and industry is vitally concerned. There is always too great a tendency for industry to try to return to a previously satisfactory order of things. Of course, this return never takes place. Those responsible for industrial research should realize that the federal government is now a permanent sponsor of research in addition to its prewar research activities in various bureaus. Industry must adopt an aggressively co-operative attitude, and itself participate in the development of a program that will help and not hinder, one which above all things is its own program, that fits its needs and does not depend upon the largess of an increasingly paternalistic government to carry the load. Otherwise there will be danger of enervation and loss of incentive.

There need never be fear of government competition, if industry develops a really worthwhile program of research and recognizes that any producing enterprise is made up of four equally important integrated parts: finance, production, sales, and research. Without any one of these components, no business can live for long.

Industry must do all in its power to stimulate fundamental research and must help finance it in the universities as well as carry out a large amount of it in its own laboratories. There is danger that this well may become dry. An investment in university research in basic science is one of the best that can be made today. It pays in three ways—the development of new teachers, the production of scientists for further industrial work, and the filling of the reservoirs of needed scientific facts.

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Appendices

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A copy of this agreement is available for your file, if desired. Please return the executed copy to the Patent Department,

Mgr.

For the sole consideration of my employment by Company, a corporation of the State of Delaware, during such time as shall be mutually agreeable to said company and myself, I hereby agree promptly to disclose, grant, and assign to said company any and all inventions and improvements relating to the business of said company which, during the period of my employment by said company, whether during or after usual working hours, or upon holidays, or at any other time while in the employ of said company, I may make or conceive, either solely or jointly with any other person or persons, together with all letters patent, and all reissues, renewals, and extensions thereof that may at any time be granted therefor or thereupon; and any and all of the same, whether made, held, or owned by me, directly or indirectly, shall be for the sole use and benefit of said company, which shall at once become entitled thereto; and I further agree, without charge therefor, but at the expense of said company, promptly at all times hereafter, to execute and deliver any and all acts and instruments in writing that may be necessary or proper in the opinion of said company to vest said inventions, improvements, and patents, and said reissues, renewals, and extensions thereof, in said company and enable it lawfully to obtain and to maintain the full right and title thereto, in any and all countries whatsoever, including all such descriptions, sketches, drawings, and other papers relating thereto as said company may need or call for from time to time, and to render said company, at its expense (including a reasonable payment for the time involved, in case I am not then in its employ), all such assistance as it may require (a) in the prosecution of applications for said patents or applications for the reissue, renewal, and extension of said patents, (b) in the prosecution or defense of all interferences which may be declared involving any of said applications or patents, and (c) in any and all litigation in which said company may be involved, relating to such patents, inventions, or improvements.

I further agree that I will not, directly or indirectly, publish, except with the written consent of said company, any information, data, or methods of manufacture of said company, and I further agree that I will, upon leaving the employ of said company, promptly deliver to said company all drawings, blueprints, letters, notes, et cetera, belonging to said company which are in my possession or under my control, and I agree that I will not make or retain or give away copies of any such drawings, blueprints, letters, notes, et cetera; and I further agree that I will not, directly or indirectly, disclose or use at any time, either during or subsequent to my said employment, any information, knowledge, or data of said company which is of a secret or confidential nature (whether or not obtained, acquired, or developed by me), unless first I shall secure the written consent of said company to such disclosure or use.

Nothing in this agreement shall be deemed to bind the said company to any specific period of employment or to bind said company to pay or continue to pay to me any specified salary.

It is understood and agreed that there are no inventions or improvements relating to the business of said company excepted from this agreement except those noted in attached statement executed by said company and made a part of this agreement.

____
(Write out name in full)

State of
City of } **ss.**
County of

____
(Dept., plant, or lab.)

On this day of , 194 , before me personally came ______________________________ (Print or type name), to me known, and known to me to be the person described in and who executed the foregoing instrument, and he duly acknowledged to me that he executed the same as and for the purpose therein set forth.

SEAL

____
Notary Public

PRINTED IN U.S.A.

PATENT AGREEMENT BETWEEN EMPLOYE AND COMPANY

This Agreement, dated.. between Company, a corporation of the State of New York, having an office and place of

business at Michigan, hereinafter called Company, and..

of.., a citizen of the United States and an employe of the Company, hereinafter called employe,

Witnesseth that:

Whereas, The employe has made certain new and useful inventions which are described

and shown on the attached prints and written matter, entitled...

....and dated.., and

Whereas, The employe desires to have the Company in its discretion, sell and/or apply for United States Letters Patent for the above inventions,

Now, Therefore, in consideration of the covenants and agreements hereinafter set forth to be performed by the Company and the employe, it is understood and agreed as follows:

1. Employe hereby sells and assigns to the Company the entire right, title and interest in and to the inventions above identified, and agrees to execute all papers necessary for a proper application for letters patent and such other papers as may be required in connection therewith, and any papers that may be necessary to confirm complete title to the inventions in the Company.
2. The Company agrees to review the above identified inventions; to consider their commercial possibilities and patentability; and either (1) to sell the inventions or to make a reasonably diligent effort to effect a sale, and/or in its discretion (2) to file and prosecute an application for Letters Patent in the United States Patent Office and to pay for the preparation and prosecution of said application without further expense to the employe, except that the Company does not obligate itself to continue indefinitely the prosecution of such patent application.
3. In the event the inventions and/or patent application and/or patent is sold, or a license is granted thereunder, the Company may retain for itself, without further payment, a license to make and/or have made for it and to use the inventions, which includes the right to the Company to purchase devices embodying the inventions from any licensee without the payment of royalty to the licensee or to the employe.
4. When and if any cash revenue is obtained by the Company from the sale of the inventions or of any rights thereunder, the Company may deduct 20% of each payment, and will pay to the employe the remaining 80% of all such revenue when received.
5. In the event that no sale of rights by the Company is completed within a period of............ years (which period may be extended by mutual consent) after the issuance of United States Letters Patent or patents covering these inventions, the Company agrees to reassign the inventions and the patents therefor back to the employe if he so requests, subject to a license to the Company as is described in paragraph 3 above.

6. In the event the Company decides to discontinue the further prosecution of the patent application or applications filed for these inventions, it agrees to notify the employe of its decision, and if the employe then desires to continue the prosecution of the patent application at his own expense, the Company will then reassign the inventions and patent application therefor to the employe, subject to a license to the Company as is described in paragraph 3 above.

WITNESSED: ....

....

....

COMPANY

ATTEST: ....

....

COUNTY OF..................
STATE OF.................... } ss:

On this day of , 19 , before me personally appeared..................

...., to me known to be the person named in and who executed the above instrument, and acknowledged to me that he executed the same for the uses and purposes therein set forth.

....
Notary Public

COUNTY OF..................
STATE OF.................... } ss:

On this day of , 19 , before me personally appeared..................

...., to me known to be a duly authorized representative of Company, the person named in and who executed the above instrument, and acknowledged to me that as such duly authorized representative he executed the same for the uses and purposes therein set forth.

....
Notary Public

Revised [illegible]
Patent Committee

EMPLOYMENT AGREEMENT

In consideration of my employment by Corporation, its subsidiaries, affiliates, assignees and/or successors in interest, hereafter called "Corporation", I hereby agree as follows:

1. That I will devote my best efforts to the interests of the Corporation and that I will work only for the Corporation during regular business hours and during such other hours permitted by law as the Corporation deems necessary, and will not work as an employee of any other person or concern while I am in the employ of the Corporation.

2. All information received by me relating to the business of the Corporation shall be deemed strictly its exclusive property and remain the Corporation's scientific, trade and engineering secrets both during and after my employment; and I shall not reveal the same to others or make use of the same in any manner except with the knowledge and written consent of the Corporation previously obtained.

3. That I will assign to said Corporation without charge to it, all my rights to inventions which I have made or conceived or which I may make or conceive, either solely or jointly with others, during the time of my employment by the Corporation, which relate to the fields of air conditioning, refrigeration, heating, cooling, ventilating and/or drying, or which are capable of being used in or in connection with the business of said Corporation as now or hereafter conducted. That after leaving the employ of the Corporation for any reason whatsoever, I will assign all my rights to the aforesaid inventions for which patent application is made within one year from the date of termination of my employment by the Corporation.

4. That without charge to the Corporation, but without expense to me, I will execute, acknowledge and deliver such papers and data, including applications for patents, as may be requested for the purpose of obtaining patents and/or other protection for the aforesaid inventions in any and all countries, and further do whatever may be required and proper to vest title thereto in the Corporation and to establish and maintain the validity thereof and to retain all the benefits of each such invention, application and patent in the Corporation and its assignees.

5. That salary for my services shall be paid by the Corporation semi-monthly and shall constitute my base salary which is the regular rate at which I am employed and that until six calendar months from the date hereof my employment may be terminated by me or the Corporation at will without prior notice, and the Corporation shall not be liable for wages or salary payments after such date of termination but after the expiration of six calendar months from the date hereof my employment may be terminated by me or by the Corporation only on the expiration of a ¼ month's notice, and after the expiration of twelve calendar months from the date hereof my employment may be terminated by me or by the Corporation only on the expiration of ½ month's notice.

6. This agreement, executed in duplicate, supersedes any and all agreements of every kind, relating to my employment and/or relating to patents and/or patent rights heretofore entered into by and between the Corporation and me. This agreement cannot be changed, nor any provision thereof waived, except by mutual consent in writing.

Dated ....(L. S.)

Employee

Witness:

.... Approved CORPORATION

By ....

An Executive Officer

AGREEMENT

THIS AGREEMENT, made and entered into by and between the COMPANY, of the a corporation duly organized and existing under the laws of the State of Delaware, party of the first part, and

party of the second part, WITNESSETH:

WHEREAS, party of the first part is engaged in the manufacture of chemicals in the City of and other places, and its market for its products is, or is in the future expected to be throughout and co-extensive with the United States, its insular possessions and territories, and other parts of the world;

WHEREAS, party of the second part represents himself to be a chemist by profession:

NOW THEREFORE, IT IS AGREED by and between the parties as follows:

FIRST: For and in consideration of the covenants and agreements hereinafter contained, party of the first part agrees to employ party of the second part as chemist, and party of the second part accepts such employment, at a monthly compensation of $ .... The employment hereunder shall be for a period of one year commencing .... and ending ....

and shall continue thereafter, subject to all the terms and conditions hereof, at the same salary (unless some other salary be mutually agreed upon from time to time), until terminated by either party at any time upon ninety days' notice in writing. Party of second part agrees that he will devote his entire time and his best efforts during the period of his employment to such duties as may reasonably be assigned to him at such places as party of first part may designate, and that he will faithfully and diligently serve and endeavor to further the interests of party of the first part during the period of his said employment.

SECOND: Inasmuch as party of second part will acquire from party of first part and its subsidiaries information respecting certain of their manufacturing formulas, processes and methods, party of second part agrees that during the term of his employment, and for a period of three years thereafter, he will not, directly or indirectly, for his own account or as an officer, member or employe of any corporation, partnership, person or persons, engage anywhere in the manufacture of, or contribute his knowledge to the manufacture of, any product or products which he manufactured or assisted in the manufacture of while in the employ of party of first part or its subsidiaries, to be sold in or shipped into any part of the United States or its insular possessions or territories or Canada; provided, however, that nothing in this paragraph shall prohibit party of the second part at any time after leaving first party's employ from engaging in the manufacture of any such product, if he manufactures the same exclusively by or according to a process or method which was in use by him, in manufacturing such product commercially, before he first entered first party's employ, or if he manufactures the same exclusively by or according to some process or method which is unlike, and makes no use of, any process or method then or theretofore in use by first party or its subsidiaries; and subject always to the further prohibition contained in the following paragraph respecting the use of first party's secret processes and confidential information.

THIRD: Party of the second part further agrees that during his employment with party of the first part and thereafter, he will not, directly or indirectly, use for himself or for others or disclose to any third party, any secret or confidential information, knowledge, or data regarding costs, uses, applications or purchasers of products made or sold by party of the first part or regarding any apparatus, process, formula or manufacturing method at any time used, developed or investigated by party of the first part or its subsidiaries, whether or not invented, developed, discovered or investigated by party of the second part while in the employ of party of the first part. Party of the second part agrees to promptly deliver to party of the first part at the termination of his employment or at any other time party of the first part may request, all memoranda, notes, records, plats, sketches, plans or other documents made or compiled by or delivered to party of the second part concerning costs, uses, applications or purchasers of products made or sold by party of the first part or any product, apparatus or process, manufactured, used, developed or investigated by party of first part or its subsidiaries during above mentioned period of employment.

FOURTH: Party of the second part further agrees that any and all inventions and discoveries, whether or not patentable, which said second party may conceive or make, either alone or in conjunction with others, during the period of his said employment, relating or in any way appertaining to or connected with any of the matters which have been or may become the subject of said party of the first part's business or investigation, or in which said party of the first part has been or may become interested, shall be the sole and exclusive property of said party of the first part, and that he will, whenever requested so to do by said party of the first part, promptly execute and assign any and all applications, assignments and other instruments which said party of the first part shall deem necessary in order to apply for and obtain letters patent of the United States and of foreign countries for said inventions, and discoveries, and in order to assign and convey to said party of the first part the sole and exclusive right, title and interest in and to said inventions, discoveries, or any applications or patents thereon.

FIFTH: This contract shall bind and inure to the benefit of successors and assigns of party of the first part, and, except as regards personal service, shall bind representatives and assigns of party of the second part.

IN WITNESS WHEREOF, the parties have hereto executed this agreement in duplicate, this .... day of

...., 19 ....

COMPANY

By.. President.

ATTEST:

.... Secretary.

....

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